SPACE ASTRONOMY

OF THE

STEWARD OBSERVATORY

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TUCSON, ARIZONA

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

GRANT NGR 03-002-032

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IMAGE DISSECTOR CONTROL AND DATA SYSTEM

PART I

October 1, 1974

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OPERATION AND MAINTENANCE FOR THE IMAGE DISSECTOR CONTROL AND DATA SYSTEM

INTRODUCTION

Under NASA sponsorship (Grants NGR 03-002-032 and NGR 03-002-153, and Contract NSR 03-002-163), the Space Astronomy Group of the Steward Observatory has been investigating the use of image dissector tubes as both remote control and data collection devices. A developmental system has been built and is now being used in laboratory programs and at the Steward Observatory 90-inch telescope (225 cm) on Kitt Peak. The acronym title of the system is IDCADS, from Image Dissector Control and Data System. A data collection and guidance assembly mounts at the Cassegrain focus of the 90-inch and is operated from a remote control console via 100 feet of cabling.

In addition to the instrumentation package for the 90-inch telescope, the control console may be used with three other instrumentation packages - a simplified telescope module for use on the 90-inch or other telescopes; a photographic plate scanner module which permits the scanning of astronomical photographic plates in the laboratory; and the Lunar Experiment package module.

This report, Part I, contains a general description of the IDCADS system, and detailed design information, operating instructions, and maintenance and trouble-shooting procedures for the four instrumentation packages. Part II contains operating procedures, detailed design information, and maintenance instructions for the control console.

I. GENERAL DESCRIPTION OF THE IDCADS SYSTEM

A. Purpose of the System

The purpose of IDCADS is to analyze two dimensional images and to relay the data to a remote location for display and/or data recording and processing. IDCADS was originally developed as a prototype for a control and display system for a possible space telescope. Such a telescope is potentially capable of such high resolution that it is believed to be impracticable to have a man (observer) too closely attached to the telescope. Motion of the man will introduce perturbations in the pointing angle of the telescope and contaminants from the life support system could complicate the problem of maintaining a "clean" environment in the vicinity of the telescope. Therefore, any operator of an optimum space telescope should be located some distance from the telescope - perhaps in a module a few miles away or on the ground. In either case, the data link between the telescope and the operating console would be via telemetry. For the prototype system described in this report, the equivalent of the data link was accomplished via a 100-foot connecting cable.

B. Use of Image Dissector Tubes for Data Collection and Image Analysis

A major portion of the effort expended under the IDCADS program has been the investigation of the use of image dissector tubes as both remote control and data collecting devices. With an image dissector tube (see Figure 1) an optical image is focused onto a photocathode; each incremental area of the cathode emits electrons at a rate linearly proportional to the light intensity on that area. A magnetic electron focusing system forms an electron image on a plate containing a defining aperture. An electron multiplier follows the aperture and generates a conventional photomultiplier output proportional to the intensity of that part of the image passing through the aperture. A deflection system displaces the electron image with respect to the aperture so that various portions of the image may be examined in sequence. ID tubes are capable of high resolution, up to 1600 TV lines per inch; with the small aperture required for high resolution the effective photocathode area is very small so that the dark noise can be low (less than 10 counts per second) without cooling.

A primary drawback frequently cited for the ID tube is that no image storage is provided, so that the photon-counting efficiency becomes very low for TV-type scans of even moderate size. Because of this, the ID tube is not an ideal device for use at faint levels over large areas. There are, however, some valuable compensating features. For example, the scan rate may be varied at will without changing the signal current amplitude and no separate image readout or erasure is required. The tube has a very wide range of linear response, at least five orders of magnitude, which virtually eliminates saturation problems. If real time guidance signals are available, an unblurred image can be generated in the presence of appreciable image motion. Operation of two tubes in parallel, one for guidance and the other for image scanning, permits achieving this capability.

1. Scan Control

Since the image dissector tubes use electrical (magnetic) deflection of the image with respect to the defining aperture in both the X and Y axes, it is possible to utilize a number of scan configurations. For IDCADS most scans follow the conventional X-Y or TV pattern. The image scan starts at the lower left-hand edge of the area to be scanned, one X-scan of "m" discrete steps is made, the scan is reset to the left edge of the scan area and indexed vertically one step, another X-scan of "m" points is made, and the process is repeated until "n" sweeps have been made, resulting in an "m" by "n" scan.

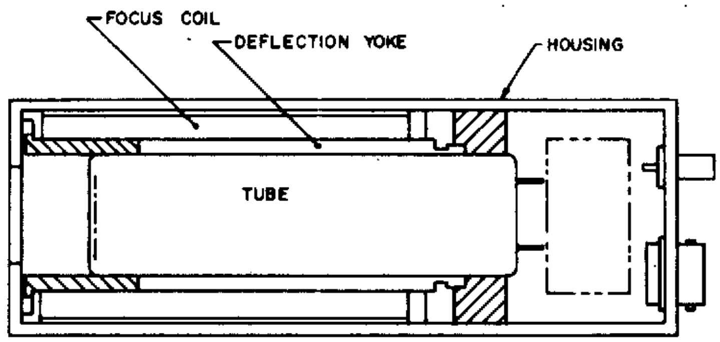

FIGURE Ia
DIAGRAM OF IMAGE DISSECTOR TUBE

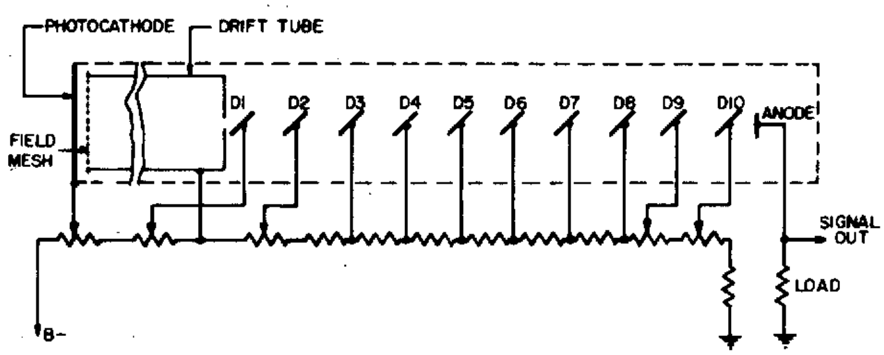

FIGURE Ib
SCHEMATIC OF IMAGE DISSECTOR TUBE

All scan parameters are digitally generated and are individually controlable, the parameters being set with thumbwheel "digital" switches on the control console (Figure 2). The starting position of the scan (lower left-hand corner) is specified by selecting an X-Y coordinate on the face of the ID tube in units of 0.001 inch by setting the thumbwheel selector switches to the coordinate desired. The raster scan of the ID tube is then added to the basic starting position. The scan dimensions may range from 1 to 1000 in either X or Y, the step size is adjustable from 0.001 inch to 0.01 inch, and the dwell time on each scan spot may be from 10 microseconds to 1 second.[1]

In practice, certain constraints apply to the scan geometry. The useful area of the ID cathode is approximately 1.1 inches in diameter, so that the maximum scan dimension (including starting coordinates) is approximately 0.8 inch without rounding or masking of the corners. If the scan data is stored in the computer, either for data analysis or for integration over repetitive scans, the maximum scan size is limited to approximately 4000 points due to present limitations in core storage locations. A typical scan may be 60 x 60, or 3600 points; note that with step spacings of 0.001 inch this results in a scan area of 0.060 x 0.060 inch. At the Cassegrain focus of the 90-inch this represents a field of view of 15 arc seconds on a side.

C. Use of IDCADS with the 90-Inch Telescope

Figure 3 shows the data collection and guidance assembly which mounts at the 90-inch Cassegrain focus. It contains two operational modules: Module I, the guidance and viewing section, contains two ID tubes; one, with a 1.5 arc second aperture, is used for viewing the field for initial acquisition of a suitable guide star or for locating the object to be scanned; the other, with a 10 arc second aperture, locks onto the guide star to provide guidance signals. Automatic gain control is employed to compensate for guide star brightness and slow fluctuations which might be caused by variable transparency. Low frequency guidance signals are sent to the telescope drive system to maintain telescope pointing; high frequency (to 30 cps) guidance signals are sent to the data acquisition module to cancel more rapid image motion due to wind deflection of the telescope tube, uneven telescope drive, and some "seeing" fluctuations.

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[1] The deflection coils currently used with IDCADS have a relatively low frequency response, limiting the maximum step rate to approximately 20,000 steps per second.

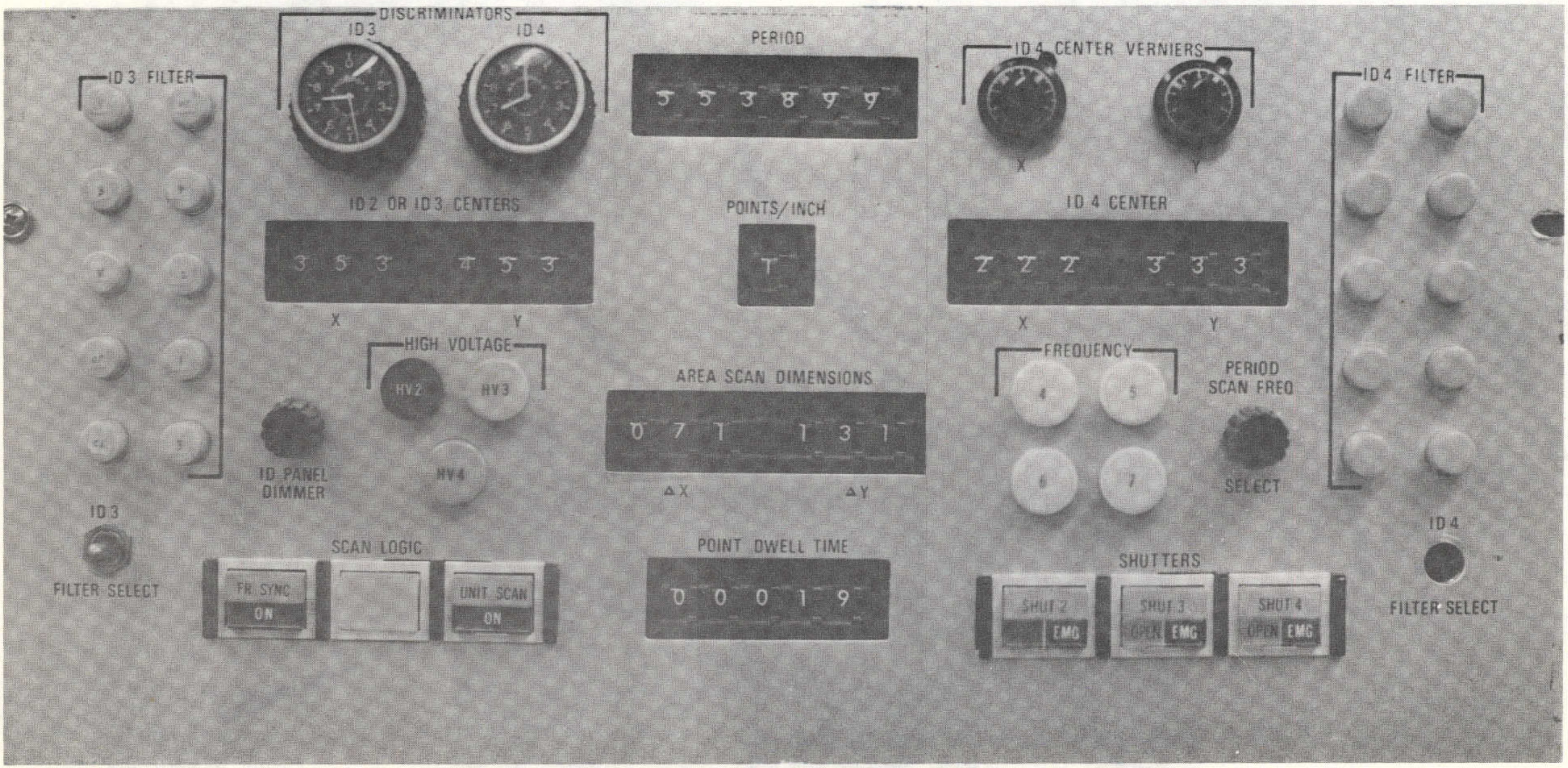


Figure 2: SCAN CONTROL SWITCHES ON CONTROL CONSOLE

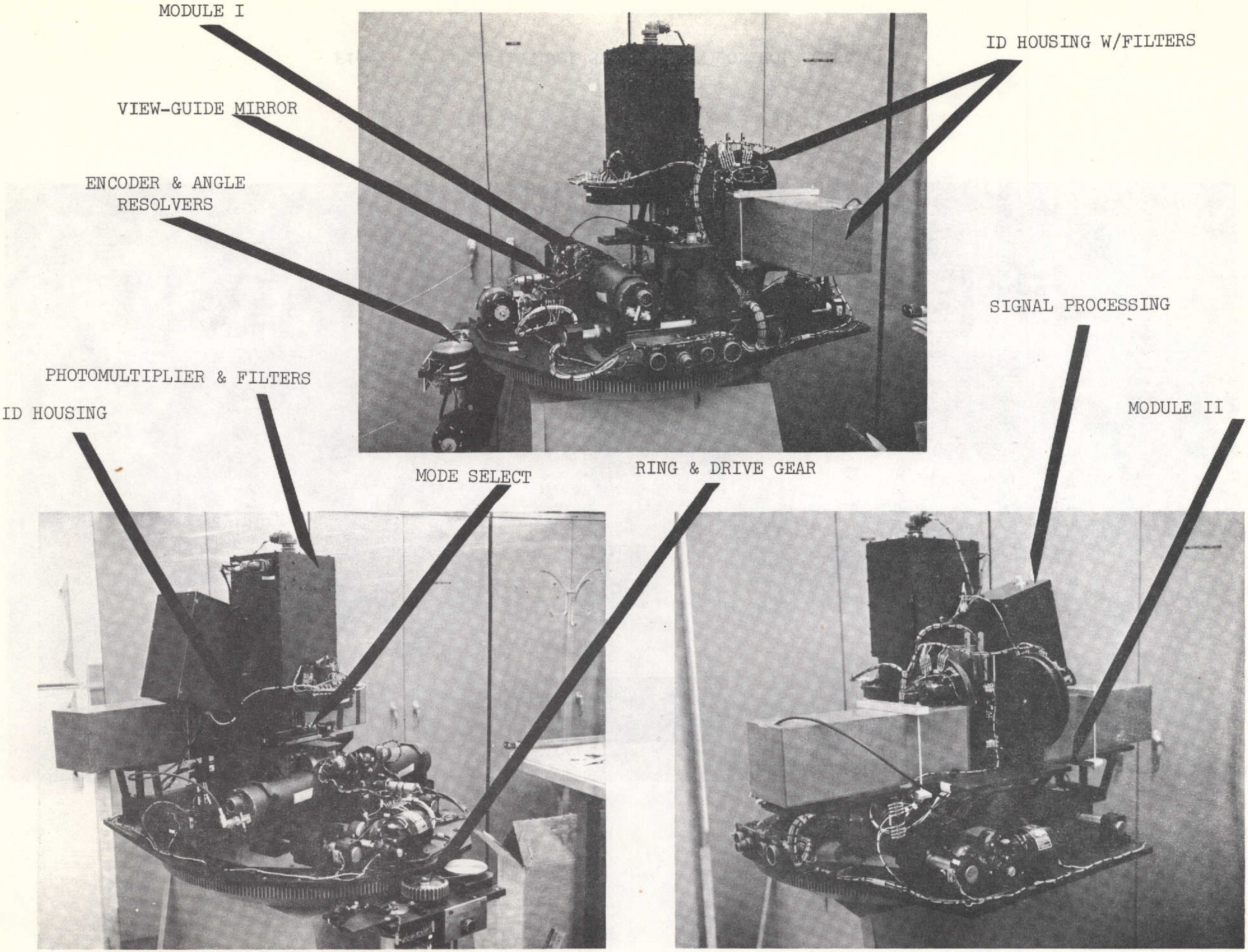


Figure 3: IDCADS TELESCOPE MODULE

Module II is the data acquisition module and contains two additional ID tubes for one or two channel area scanning (each with an 0.6 arc second aperture) a photomultiplier tube for normal aperture photometry and a visual eyepiece which could be exchanged for a film assembly for field photography. Focal plane aperture photometry is designed with normal fabry optics operating on the real image in the telescope focal plane. For film imaging or area scanning, a 1:1 transfer lens is employed for reimaging. The guidance signals generated from Module I are applied to Module II in various ways according to the type of observation being made. In photoelectric photometry, the focal plane aperture is physically displaced to track the object; film imaging will employ lateral shifts of the transfer lens to provide image stability; image dissector scans are stabilized by electrical addition of the guidance error signals to the scan location.

Figure 4 shows the telescope assembly mounted to the 90-inch telescope. The guidance and data modules are mounted on an adaptor plate which contains a ring gear so that the assembly may be rotated to any angle with respect to the telescope. Linear (radial) motion of modules I and II in combination with rotation thus result in a polar coordinate offset system so that any portion of the telescope field may be used. Normally, data acquisition is on axis and guidance is done in the peripheral field.

The telescope assembly is connected to the four bay control console shown in Figure 5 through a connecting cable. Approximately 250 control or signal wires are required; multiplexing is employed to reduce the actual number of wires to less than 150. The control console provides power, experiment control, data processing and recording, and data display. As indicated in the figure, the various functions performed by the console are grouped together by function, with different sections of the console providing control of guidance, selection of operational modes, data display photometric controls, and image dissector scan controls. The console also houses data recording ad processing devices, a printer, an incremental tape recorder, and a small computer.

D. Use of IDCADS with Other Instrumentation Packages

Several other instrumentation packages have been developed for specialized applications which utilize portions of the control circuitry and data analysis instrumentation of the control console.

1. Simplified Telescope Package (Module III)

Figure 6 shows a simplified instrumentation package (Module III)

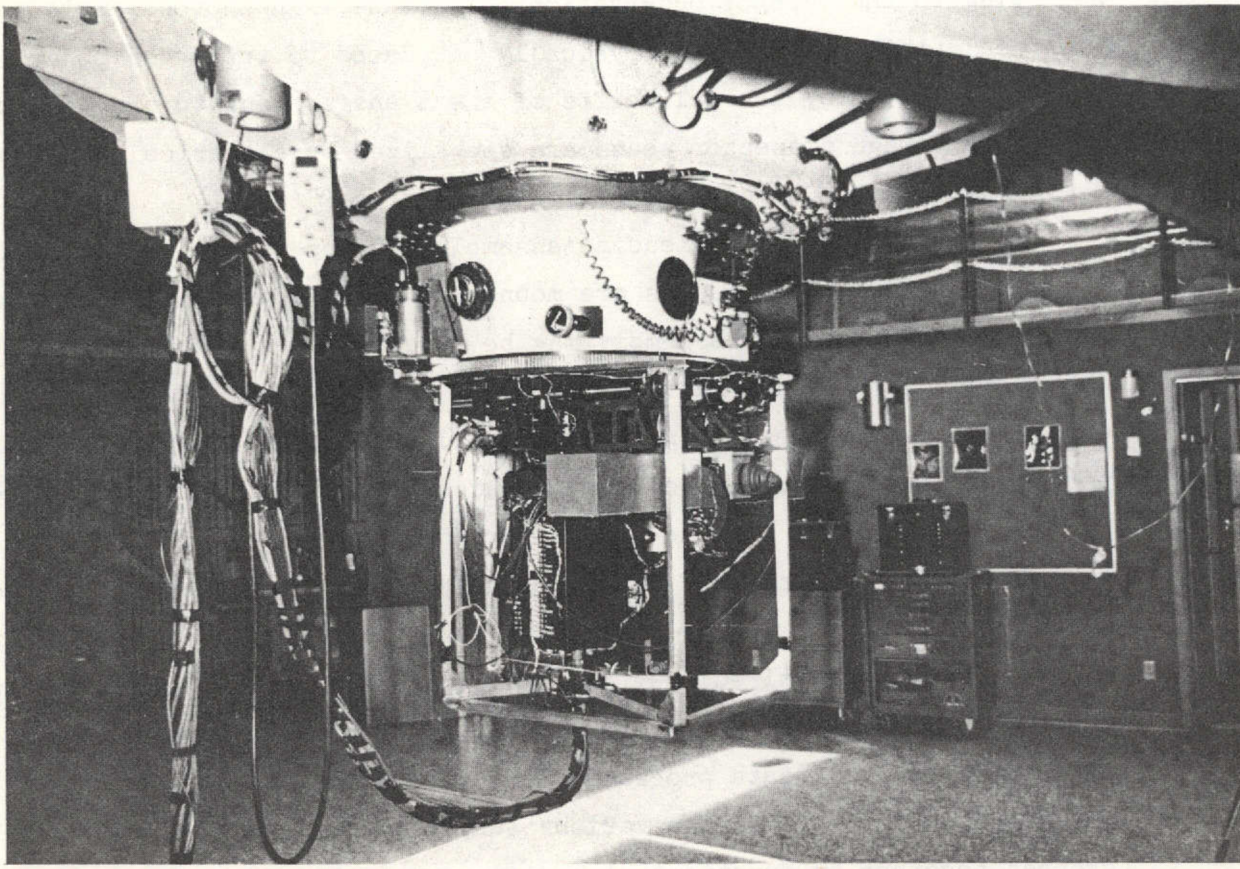


Figure 4

IDCADS TELESCOPE MODULE INSTALLED AT 90-INCH

TELESCOPE CASSEGRAIN FOCUS

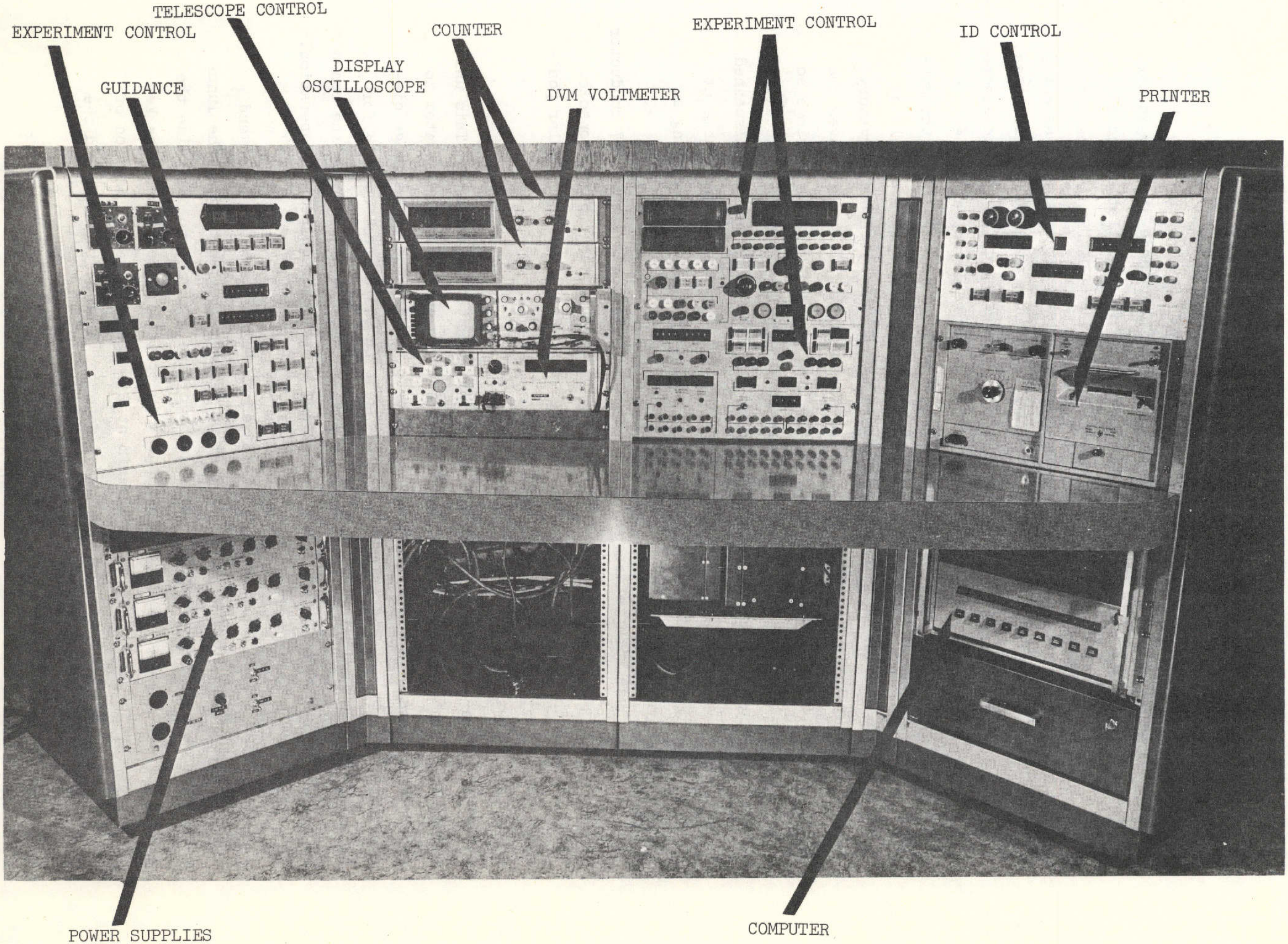


Figure 5: IDCADS CONSOLE SYSTEM

intended for performing image dissector scans with telescopes other than the 90-inch or for simplified practical observations on the 90-inch. The system permits maximum optical efficiency by placing the ID cathode directly in the telescope focal plane. The system also permits rapid installation and dismantling. Guidance with Module III is not provided by IDCADS. For use with the 90-inch, Module III fits on the same adaptor plate and ring gear assembly as the regular telescope instrumentation unit. For use with other telescopes, Module III requires an adaptor plate specifically designed for each telescope.

Module III contains a single set of guide rails which carries two observing units — an eyepiece and an image dissector tube. For use, the eyepiece is moved to the center of the field of view. This eyepiece could be replaced by a TV viewing system presently in use at the Steward Observatory. The eyepiece is then driven to the side of the module; this motion moves the ID tube to the center of the module. Mechanical stops index the carriage so that the object of interest is at the center of the ID cathode. By actuating the scan circuitry from the control console, the object may be viewed/scanned as desired. Guidance is provided by whatever normal means are available at the telescope, either visual, TV, or image dissector auto guiding using an IDCADS-like system.

For use with telescopes other than the 90-inch, a special 37 conductor cable is used to connect the instrumentation package to the control console. For use with the 90-inch, a total of 98 wires are used since the angular position readout of the ring gear is included.

2. Plate Scanner

Figure 7 shows the Plate Scanner instrumentation package. This unit contains a plate holder, a collimated light source, and an optical system to project an area of the plate being scanned onto the cathode of an image dissector tube. The output of the ID tube is sent to the control console for data display and analysis, as with the other systems. Connection to the console is through a special 15-foot cable containing the wires required for operation.

3. Lunar Experiment Package

Under NASA Grant NGR 03-002-153 an experiment was developed and proposed for use under the ALSEP program to perform site testing on the lunar surface to evaluate the optical environment of the moon and to determine the long term effects of the lunar environment on optical performance. The key technique proposed for the Lunar Experiment Package was the utilization of image dissector tubes for the viewing of detector plates, the sky, and the

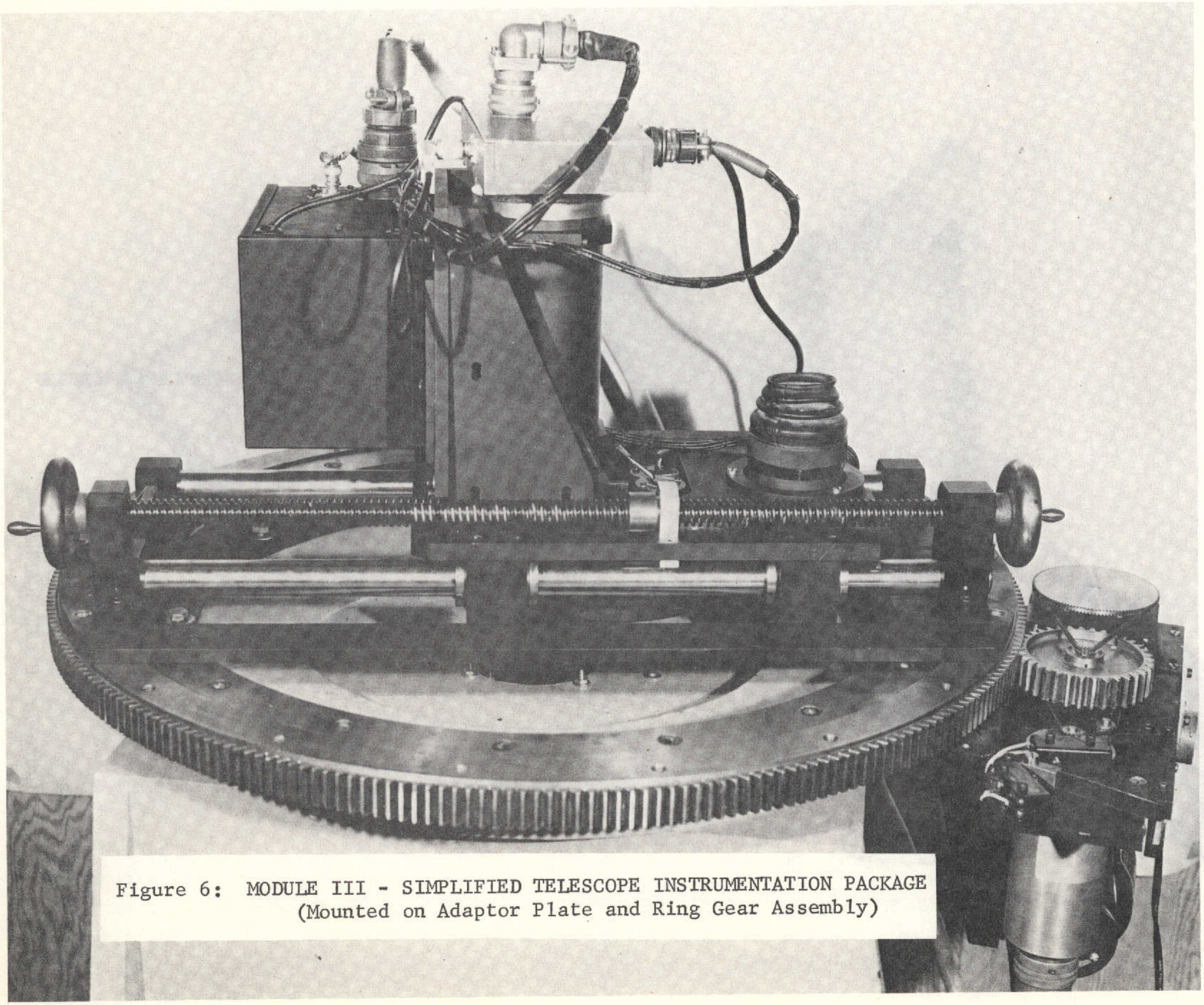


Figure 6: MODULE III - SIMPLIFIED TELESCOPE INSTRUMENTATION PACKAGE
(Mounted on Adaptor Plate and Ring Gear Assembly)

Figure 7: PLATE SCANNER

terrain.[2]

A laboratory feasibility model was constructed (see Figue 8) which combined an ID tube with the necessary optical elements to form ID microscopes, 10X and 50X (for high resolution scanning of detector plates or optical substrates exposed to a simulated lunar environment), or an ID telescope (for sky brightness measurements and telescopic sky imaging). For the laboratory model, a single ID tube was used with the optical elements being indexed in and out to complete the microscopes or telescope. The instrumentation package was controlled and evaluated with the IDCADS control console, with scans being performed in the same manner as with the other instrumentation packages. Connection to the console was made with the regular 90-inch instrumentation cables.

II. THEORY OF OPERATION OF MECHANICAL AND OPTICAL SUBSYSTEMS

A. Primary Instrumentation Package

The primary instrumentation package, which was shown in Figures 3 and 4, is intended for use of IDCADS on the Steward Observatory 90-inch telescope. It consists of three subassemblies — (1) the telescope adaptor plate and ring gear, (2) Module I, containing two image dissector tubes for acquisition and guidance, and (3) Module II, containing a variety of detectors — for data collection.

1. Telescope Adaptor Plate and Ring Gear

In order to facilitate the attachment and control of the instrumentation package to the 90-inch telescope, an adaptor plate and ring gear assembly (see Figure 9) is first attached to the telescope at the guider adaptor flange near the Cassegrain focus. The adaptor plate, which has a 19-inch inside diameter, is securely fastened to the guider interface and serves as the mount for the inner race of the ring gear (fixed race), which is coupled to the adaptor plate so that the gear's outer race (which has external teeth) is free to rotate. The instrumentation unit is then mounted to the ring gear (outer race), so that it is free to rotate with respect to the telescope's central viewing axis.

The ring gear has a pitch diameter of 28 inches and a tooth pitch of 3.2 teeth per inch, giving a total of 280 teeth. This gear, together with a

[2] For a more complete description of the Lunar Experiment Package, see Space Astronomy Report No. A 71-6, "Final Technical Report of NASA Grant NGR 03-002-153," June 30, 1971.

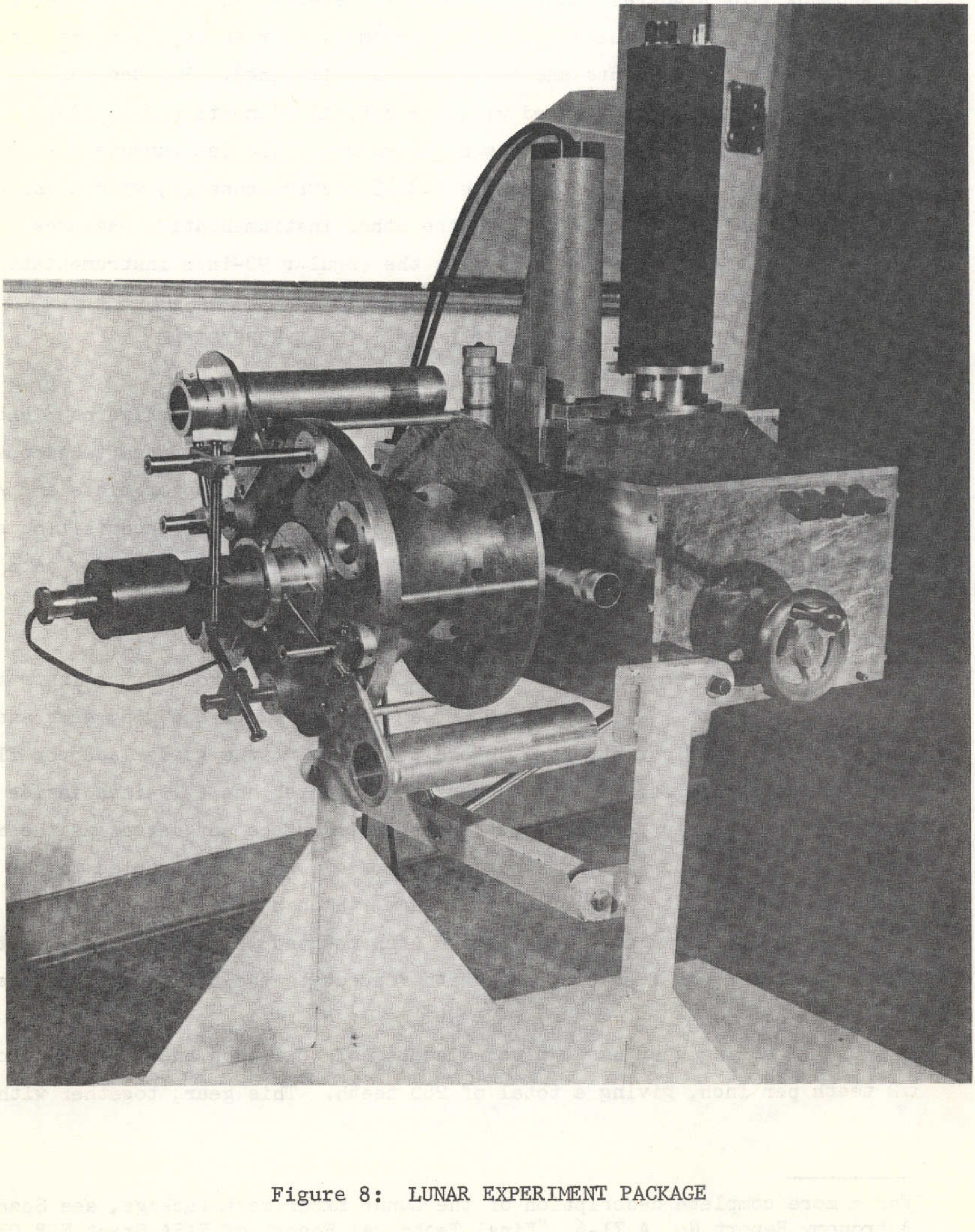


Figure 8: LUNAR EXPERIMENT PACKAGE

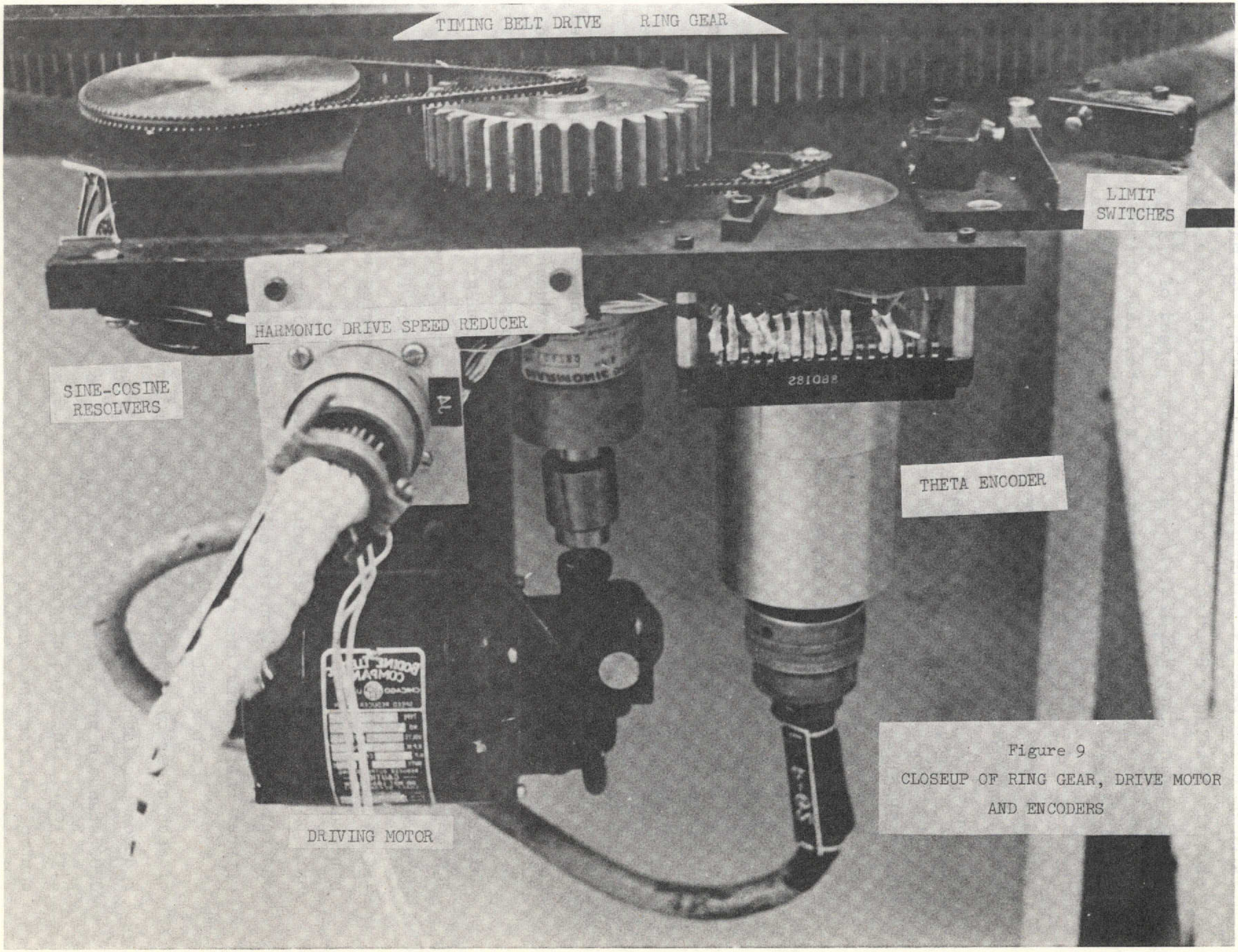


Figure 9
CLOSEUP OF RING GEAR, DRIVE MOTOR AND ENCODERS

matching drive gear (3.5-inch diameter, 35 teeth), was machined to special order by Messinger Bearing Incorporated. A variable speed gear reduction motor (Bodine type NSH-12R, 1/50 HP, maximum speed of 173 rpm) is coupled to the drive gear (35 teeth) through a zero-backlash United Shoe Machinery Harmonic Drive 100:1 reducer so that the ring gear may be driven at a maximum rate of 90° per minute. The ring gear itself is capable of continuous rotation, but "limit" switches are provided to restrict the rotation to a total of 400° so that connecting cables will not become twisted.

Coupled to the drive shaft through 1:4.5 step-up instrumentation gear and timing belt is a 36-speed angle position encoder (Theta Decitrack Model TR-511-c), which indicates the position of the ring gear as five decimal units to a resolution of 0.01° (from 000.0° to 360.0°). The precision of the ring gear, the drive gear, and the speed reducing units is such that nonlinearities, hysteresis, and backlash are held to less than 0.01° resolution.

Also coupled to the drive shaft through an 8:1 speed reduction is a two-gang sine-cosine potentiometer which is used for polar-to-Cartesian coordinate transformation, as will be described in Section II.A.2.b. Figure 9 is a close-up of drive motor and encoders.

After the telescope adaptor plate and ring gear have been attached to the telescope, a mounting plate containing instrumentation Modules I and II is fastened to the body of the (outer race) ring gear (described earlier). This mounting plate contains two parallel precision-ground and hardened 1.250-inches diameter guide rails. Modules I and II are mounted on these guide rails, each being supported by three Thompson linear ball bushings. Two of the three bushings are side loaded by a spring to compensate for possible un-parallelism of the rails. This loading is in a single perpendicular axis to the rail. The three-point suspension (two spring loaded bushings on one rail and one fixed on the other) is used to insure mounting each module without introducing the stresses which could occur with a four-point design.

Each module may be positioned along the guide rails independent of each other by a precision lead screw and nut which is preloaded, this reduces backlash and hysteresis essentially to zero. (The screw is an 0631-0200 standard precision .200 lead R.H. nut to match, Saginaw Steering Gear Division.) The lead screws are driven by variable speed Bodine motors controlled from the console. Speed of travel is adjustable from zero to 0.5 inch per second. Ten-turn wire wound 0.1% potentiometers are coupled to the lead screws through timing belts. The potentiometers are supplied with a regulated voltage, such that each volt output from the potentiometer (as measured with a digital voltmeter on the console) indicates 1.000 inch of travel of the module. The total travel of each module is five inches, so that either module may be positioned anywhere from the center of the field of view of the telescope to outside the field of view (the field of view of the 90-inch is approximately eight inches in diameter, or a radius of four inches). Limit switches and interlocks deactivate the drive motors when the modules approach the limit of their travel or when they threaten to collide with each other.

The combined motions of the ring gear (angular) and the modules (linear) result in a polar coordinate, or R-θ, coverage of the entire field of view of the telescope; that is, any point in the field of view (8-inches diameter) may be viewed by either module by driving the instrumentation package to the proper angle, θ, and the proper radius, R. These drive controls, called R_1, R_2, and θ are located on the console as shown in Figure 10. Each motion is individually controllable, with speed variable from zero to maximum and the direction reversable. The polar coordinate position is indicated on the console, the angle being presented continuously on the Theta readout and the radial position R_1 or R_2 on the digital voltmeter when the voltmeter selector switch is turned to those positions.

2. Module I — Viewing and Guiding

Module I was shown in Figure 3. The module contains two image dissector tubes; ID-1, with an 0.040-inch aperture, is used for guiding and ID-2, with an 0.006-inch aperture, is used for viewing. Only one tube may be used at a time; a View-Guide mirror has a third position in which neither tube is in service. This position allows easy access for cleaning and also keeps bright light from accidentally entering either tube.

The image tubes are packaged in light-tight cylindrical housings as shown in Figure 11. In addition to providing a method of mounting and indexing the ID tube and its focus and deflection coils, the housing incorporates the high-voltage resistor divider chain (as shown in the schematic of Figure 1b), a signal preamplifier, and a shutter. The guidance ID tube has a separate 510 volt dry cell to supply the cathode-to-drift tube voltage so that the electron beam will remain in focus even though the dynode voltages are changed by an automatic gain control which maintains a constant guidance signal independent of signal strength (i.e. magnitude of the guide star).

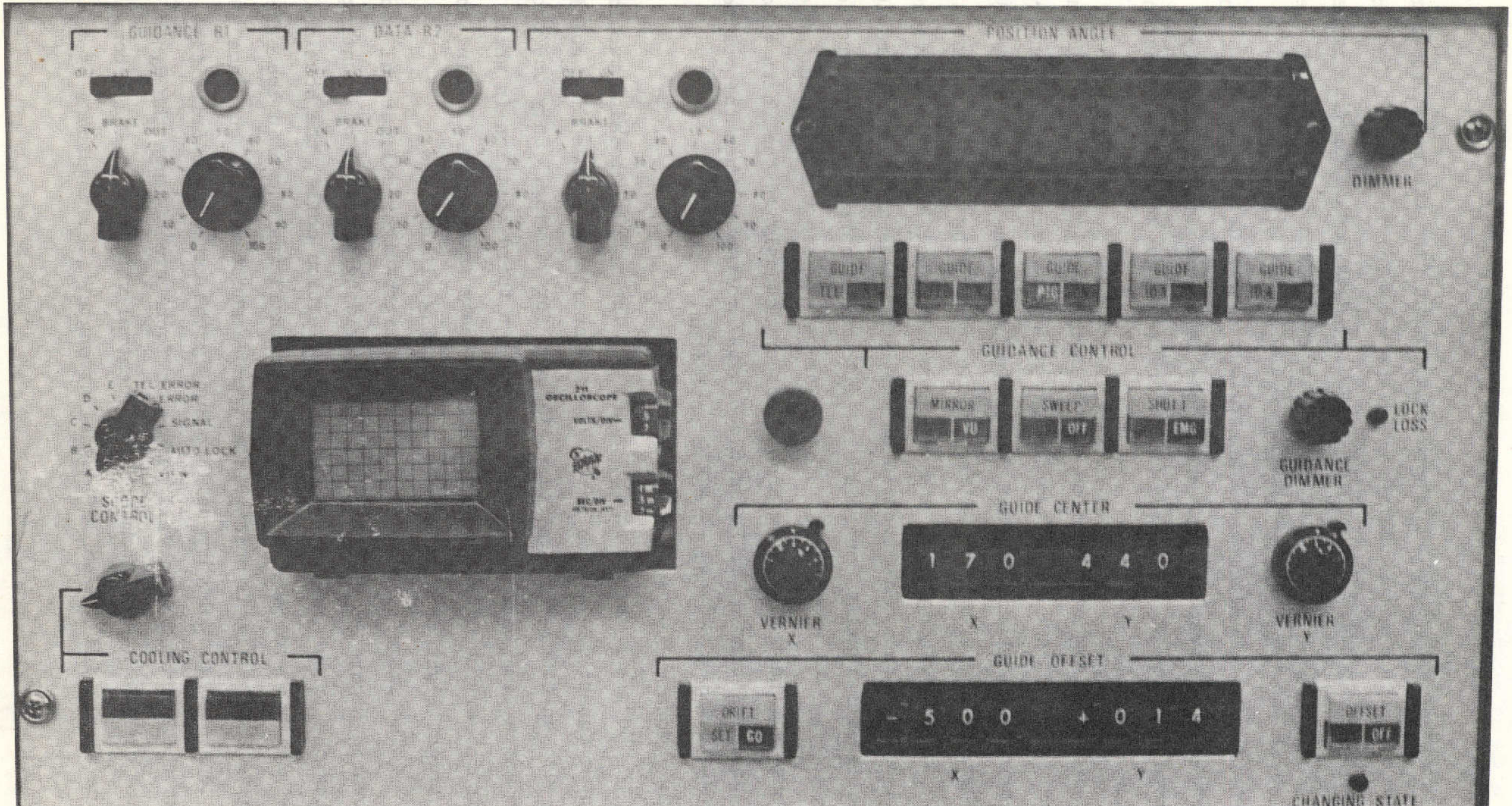


Figure 10: CONSOLE READOUTS AND CONTROLS FOR R_1, R_2, AND THETA

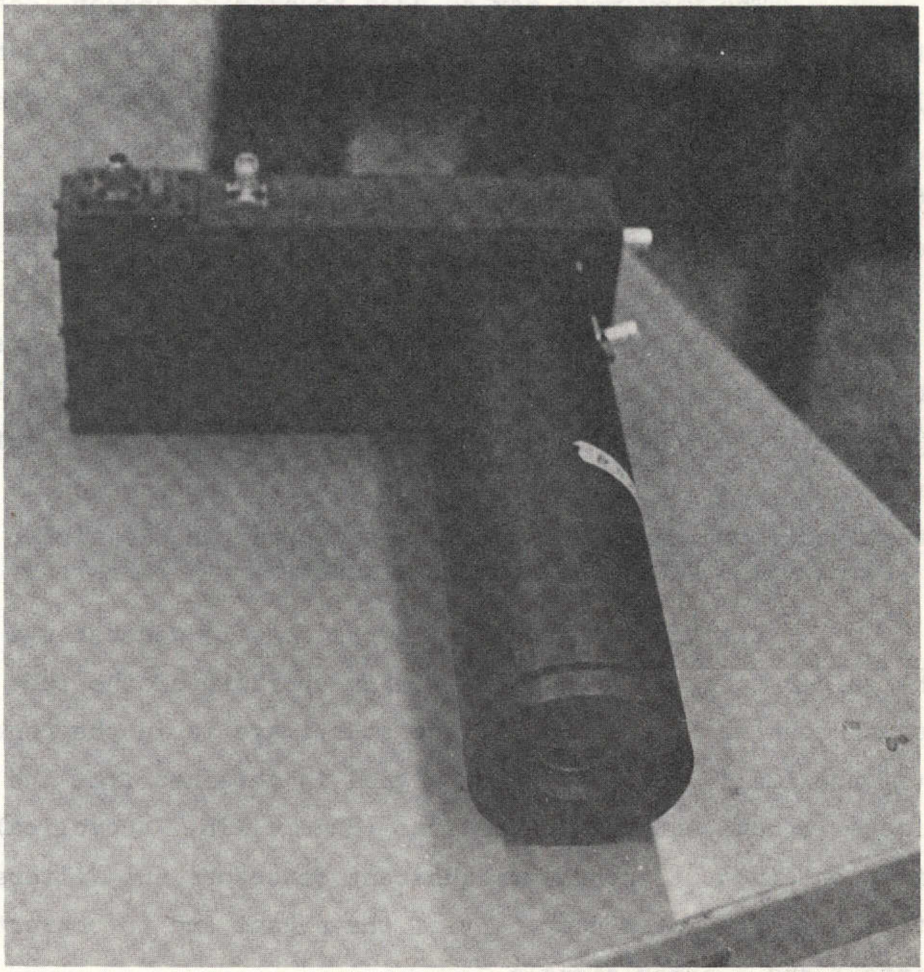


Figure 11: IMAGE DISSECTOR TUBE HOUSING

a. Viewing

For viewing, the View/Guide Mirror is positioned to the VIEW position using the control switch on the console. Module I is positioned with the R-θ drives until its center is at the position of interest in the field of view of the telescope. When the shutter is opened to the view guide tube (ID-2) a TV-type view is obtained on the viewing oscilloscope at the console after proper operation of the scan controls (see Section I.B.1.).

The view mode may be used to examine and/or locate an object of interest for further analysis by Module II, the data collection module. Usually, however, the object of interest for data collection is visually located using the eyepiece (ERFLE wide angle) on Module II in conjunction with the wide field eyepiece located on the telescope's offset guider and the telescope is driven until the object of interest is in the center of the field of view; the view mode of Module I is then used to locate a suitable guide star in the peripheral field of view. The R-θ drives are actuated so that the guide star is near the center of the photocathode of ID-2; then the View/Guide Mirror is actuated to the GUIDE position and the guide star is acquired and "locked-on" with ID-1 when the shutter is opened. Normally predetermined coordinates are used in guide star acquisition.

b. Guiding

Electronic circuitry in the console generates a circular scan for the guider tube, so that the defining aperture of the tube is moved in a circle as shown in Figure 12. If the star image is in the center of the scan (Figure 12a), a steady output signal is obtained from the tube. If the star image is not centered in the scan (Figure 12b), a cyclically varying output is obtained. Synchronous quadrant detectors and filters are utilized to detect any off-center component of the signal and to convert the displacement into X and Y error signals.[3]

The scan rate is 1,000 scans/second; the filter networks reduce the frequency response of the guider to approximately 30 hz/second, sufficiently high to correct for fluctuations in "seeing", telescope vibrations due to wind, uneven telescope drives, etc. The error signals may be fed to each of the data analysis detectors and to the telescope drive. For image tube scanners the error signal is electrically added to the deflection coil

[3]This is a greatly simplified description of the portion of the guider; for a more complete description see Volume II.

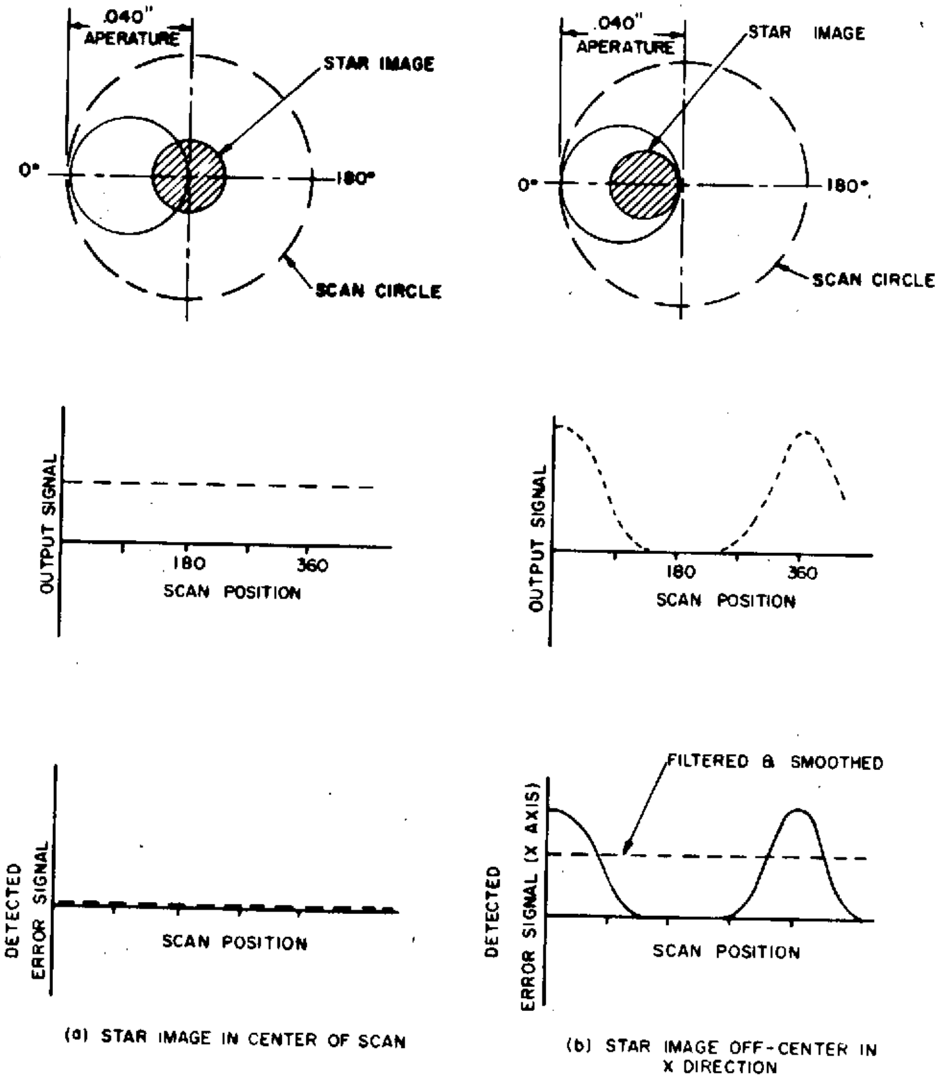


FIGURE 12: IMAGE SCAN & ERROR SIGNAL FOR GUIDER TUBE

drive. For aperture photometry the focal plane aperture is physically displaced to track the image (see Section II.A.3. for details); film imaging employs lateral shifts of the transfer lens to provide image stability.

Correction signals developed by the guider are X-Y errors as referenced to the instrumentation modules. Corresponding errors referenced to the telescope as declination and right ascension signals will vary as a function of the instrumentation package orientation angle, (θ) Theta. The error signals are routed through a buffer-amplifier-resolver circuit (schematic shown in Figure 13) to affect coordinate transformations:

$$\varepsilon_{\delta} = \varepsilon_{x}\mathrm{Cos}\theta + \varepsilon_{y}\mathrm{Sin}\theta \qquad \varepsilon_{\alpha} = -\varepsilon_{x}\mathrm{Sin}\theta + \varepsilon_{y}\mathrm{Cos}\theta \tag{1}$$

Amplifiers A_1 and A_2 are inverters to provide both plus and minus error signals to the dual sine-cosine resolver potentiometers; amplifiers A_3 and A_4 perform the required mathematical operation on the output of the resolvers. The declination and right ascension error signals are then fed to the telescope drive circuits, where they are superimposed on top of the regular clock-drive tracking signals. Note that fast response of the telescope is not required. High frequency error signals are sent to the data analysis detectors so that the image is stabilized; guidance signals are sent to the telescope only to prevent the slow build-up of large tracking errors.

3. Module II — Data Gathering

Module II was shown in Figure 3; this module is the data acquisition module and contains a variety of detectors; (a) two image dissector tubes for performing area scans, (b) a photoelectric detector for aperture photometry, and (c) a photographic unit or eyepiece. In addition, the module contains an optical mechanical assembly for selection of the operating mode, a transfer lens, a signal processing unit, and a calibration assembly.

a. Image Scanning (image dissector tubes ID-3 and ID-4)

Module II contains two identical image dissector tubes, ID-3 and ID-4, each with an 0.0025-inch aperture. The housing for these tubes is similar to that for ID-1 and ID-2, except that a filter wheel is added ahead of the shutter, and the tubes' housings are enclosed in a phenolic box for future cooling. The filter wheel may be indexed to any one of ten positions, one position is normally a clear aperture, a second is an opaque window. Eight bandpass filters complete the set. The filter wheel is driven with a bi-directional stepping motor (28 VDC, 10 position, 36°/step). A continuous turn potentiometer is coupled to the filter wheel to transmit a voltage to

EQUATION: $\Sigma x = \Sigma x \cos\theta + \Sigma y \sin\theta$

$\Sigma x = -\Sigma x \sin\theta + \Sigma y \cos\theta$

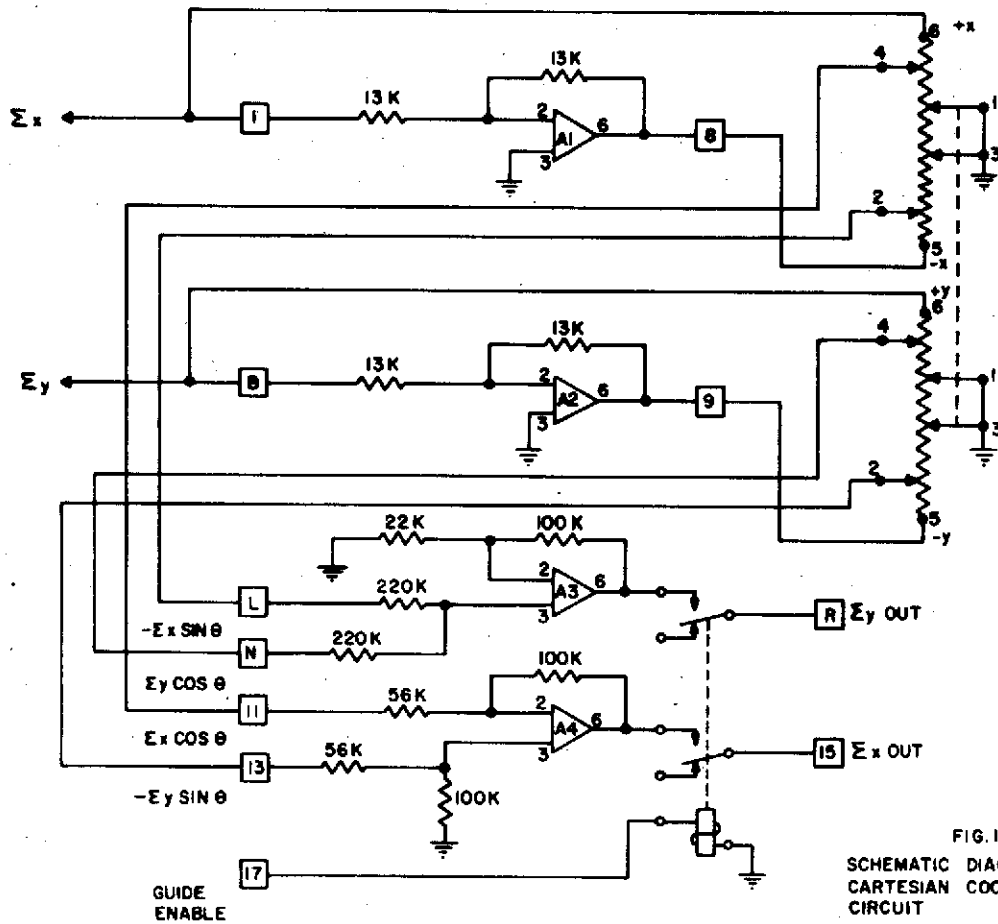


FIG. 13

SCHEMATIC DIAGRAM OF POLAR-TO-CARTESIAN COORDINATE TRANSFORMATION CIRCUIT the console to indicate which filter is in position.

ID-3 and ID-4 are used for area scans as was described in Section I.B.1. Usually, only ID-3 is used, obtaining a scan of the object of interest in the spectral region of interest. However, it is possible to employ a beam splitter (see Section II.B.1.) so that the object of interest is simultaneously viewed by ID tubes 3 and 4; simultaneous area scans may be performed with each ID tube. If different filters are selected for the two ID tubes, simultaneous scans are obtained in different spectral regions, so that bi-color comparisons may be made.

b. Aperture Photometry (photomultiplier)

Aperture photometry is done with normal Fabry optics operating on the real image in the telescope focal plane. An aperture wheel is located at the image plane; any one of 23 positions of the aperture wheel may be selected for use; 22 positions include the following aperture sizes: 400μ, 600μ, 800μ, 1000μ pin holes, ″.052, ″.063, ″.076, ″.089, ″.106, ″.120, ″.136, ″.157, ″.177, ″.196, ″.219, ″.234, ″.261, ″.302, ″.312, ″.339, ″.368, and ″.390 diameters. Position 23 is a 1″.25 diameter clear aperture which permits the entire image area to be relayed with a transfer lens to the image dissectors for area scanning or to the eyepiece or a photographic unit for field photography. The aperture wheel is stepped by a Slo-Syn stepping motor, 200 steps per revolution, 1.8° per step. A 9-bit shaft-position-to-digital encoder (Norden type ADS-ST-8-GRAY a) is coupled to the aperture wheel, so that up to 256 positions of the aperture wheel may be detected if needed; a diode decoder network in the console is used to interpret which of the 23 aperture positions is being used.

The photomultiplier tube (EMI #6256 or EMI #9958) is contained in the housing shown in Figure 14, which incorporates a shutter and two ten-position filterwheels in tandem. Each filter wheel contains one clear position, so that a total of 18 possible filters may be used for photometry. Position read-out on the filter is identical with that for ID tubes. The housing is insulated with foamed-in-place polyurethane foam and contains a four-stage Melcor Thermoelectric Cooler (first stage is water cooled), which is capable of cooling the photomultiplier to a temperature of -80°C to reduce the dark count to a negligible quantity. A preamplifier conditions the signal output from the photomultiplier. Figure 15 shows the controls and status indicators on the console which are used during the operation of the photometer.

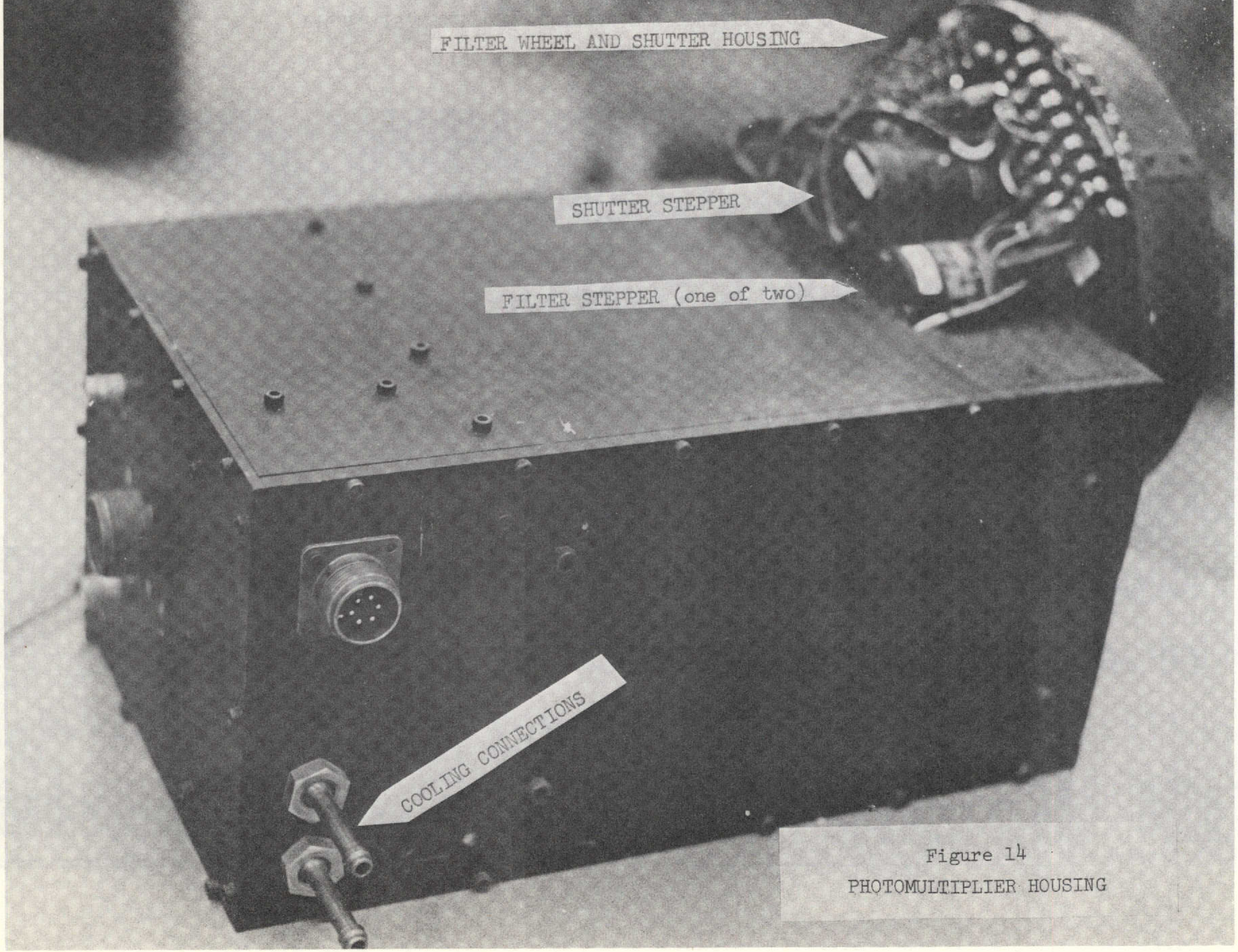


Figure 14
PHOTOMULTIPLIER HOUSING

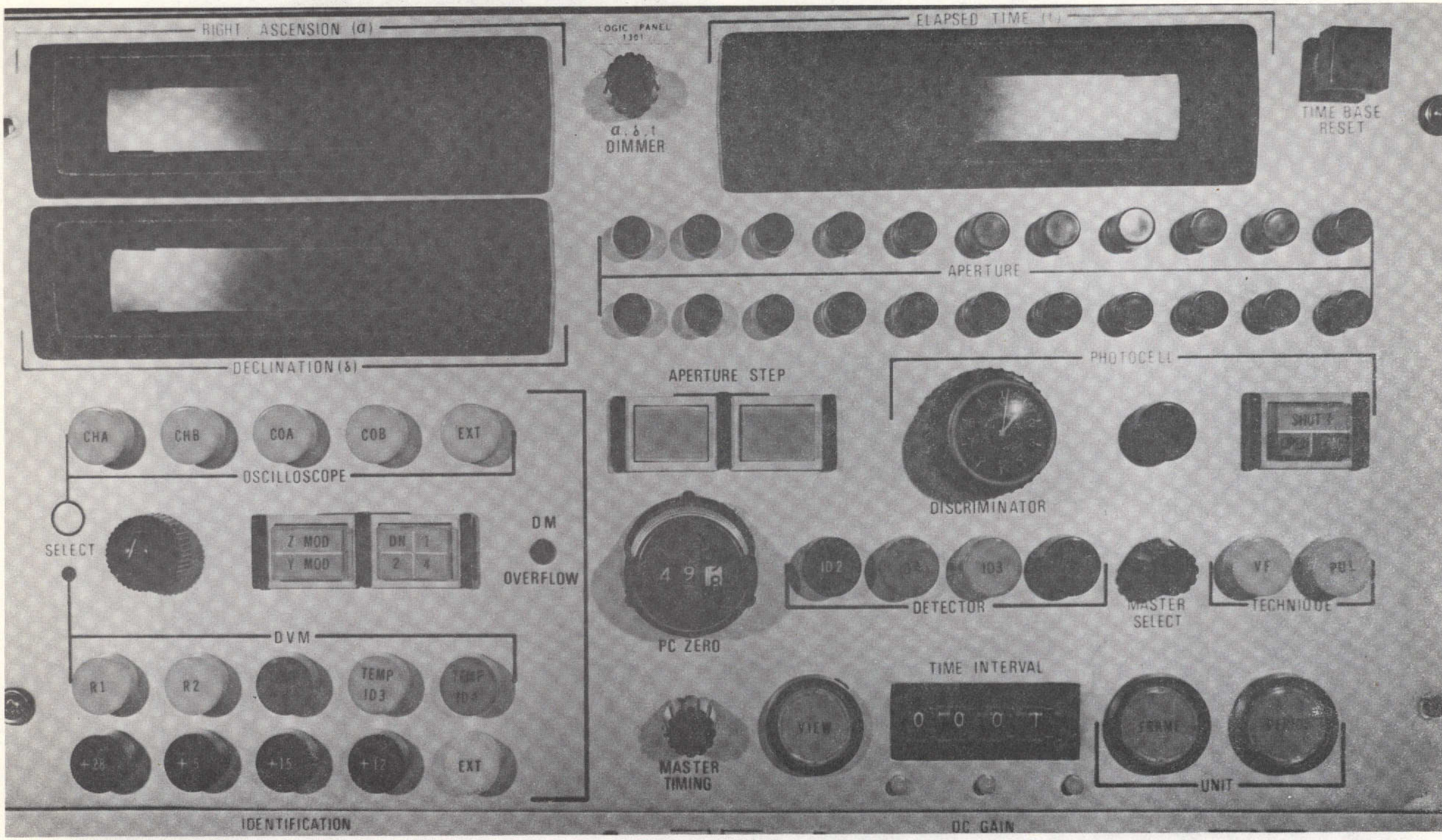


Figure 15: CONSOLE CONTROLS FOR OPERATION OF PHOTOMETER

c. Photographic (direct view position)

The "clear" position of the detector select assembly permits a portion of the telescope field to be relayed to the "direct view" position. This position may be occupied by the photographic unit, as shown in the schematic of Figure 16, by an eyepiece for direct examination of the field area to be studied, or perhaps, in the future, a TV-type pickup for remote viewing of the field.

The photographic unit has not as yet been completed. It will consist of a 4"x5" photographic plate held in a plate holder; each picture is approximately one inch in diameter, so that by repositioning the plate between exposures, a number of pictures may be taken on one plate. The photographic unit will have a remotely operated shutter and a ten-position filter wheel. The unit will also incorporate a calibration system which will consist of an illuminated clock, a calibration lamp, and miniature optics to project an image of the clock and a variable density calibration wedge onto the film near the field exposure. The shutter is so arranged that an image of the clock is obtained both during the opening and closing of the shutter; this double exposure indicates the starting and stopping times of the frame. The calibration wedge is "on" while the shutter is open, so that a sensitivity calibration of the film is obtained during the actual exposure. Figure 17 shows a system of the type which is intended for this instrumentation unit.[4]

d. Operating Mode Selection System (mode select)

Because lack of space resulted in physical interference, it proved to be impossible to locate all of the detector devices directly at the focal plane of the 90-inch telescope. Therefore, only the aperture diaphram plate for photometry is located at the image plane and an optical relay system, consisting of a field lens, a transfer lens, and two mirror/beam splitter assemblies (Detector Select and Mode Select) are used to direct images or calibration signals to the image dissectors and the photographic unit.

An optical schematic of the system is shown in Figure 16. Elements which are an active part of the optical relay are the Mode Select Assembly ("B" on the diagram), the Transfer Lens ("C"), and the Detector

[4] System developed in 1967 under a NASA Apollo AAP Program for a far ultra-violet camera.

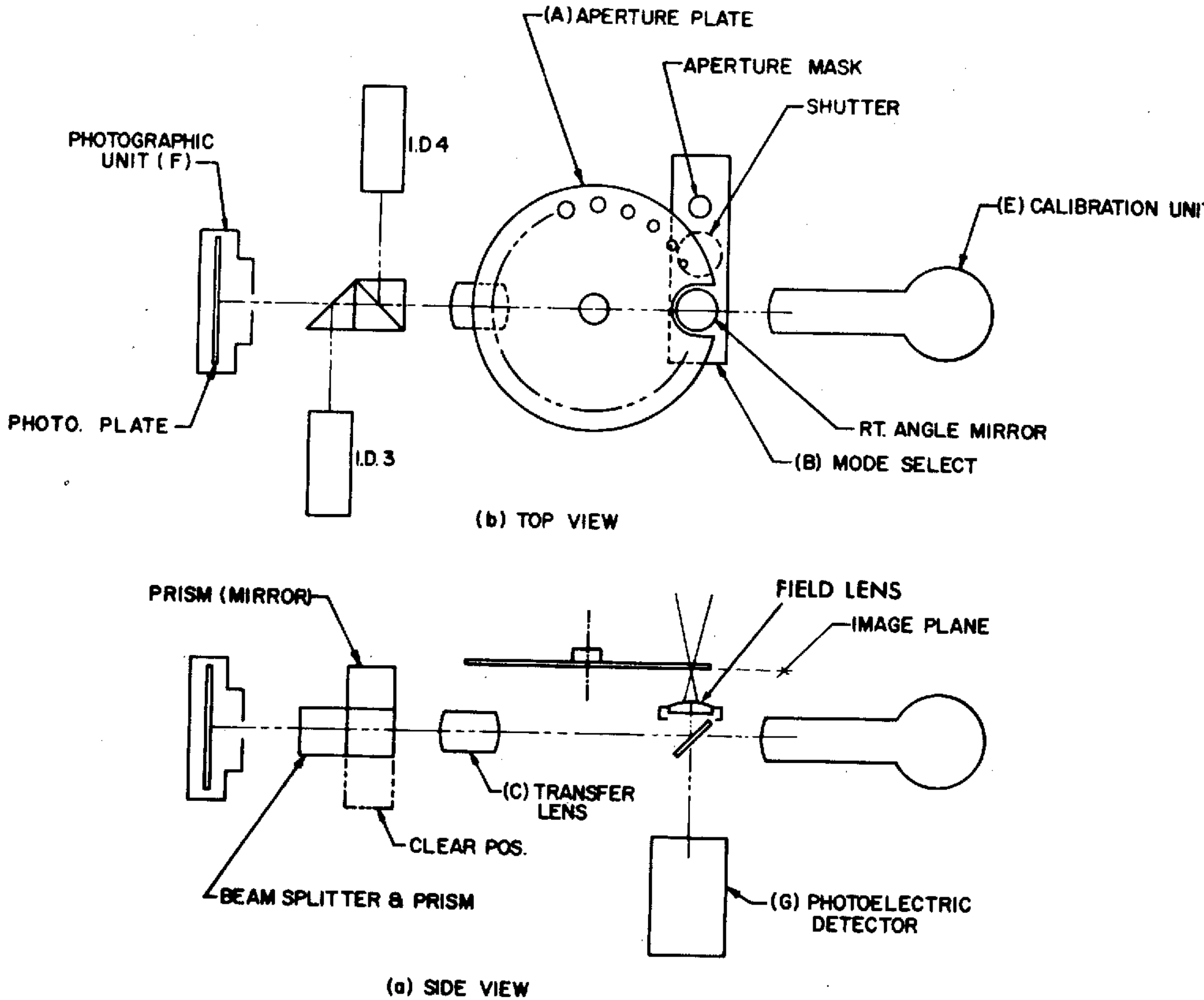


FIGURE 16 : OPERATING MODE & DETECTOR SELECT

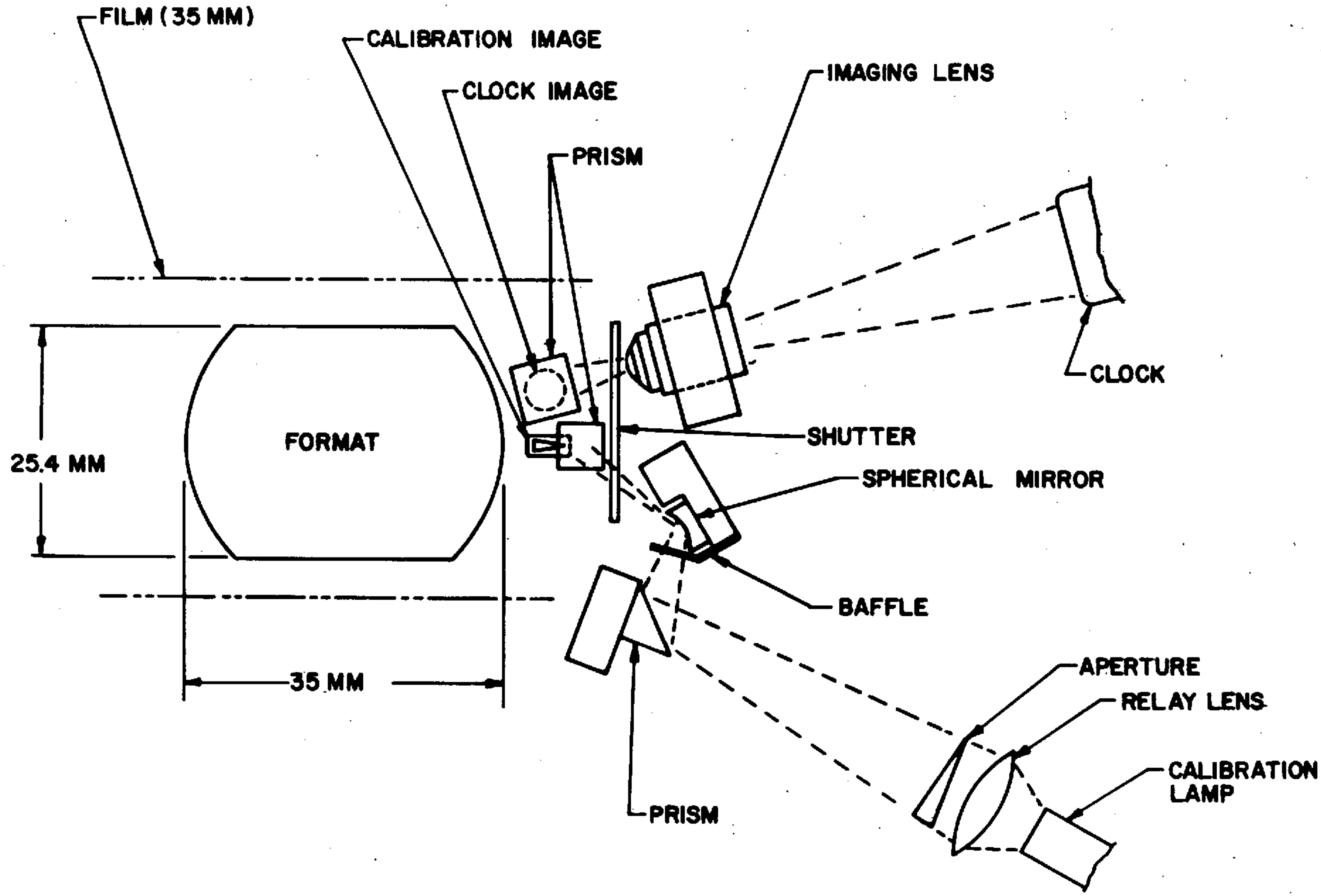


FIGURE 17 OPTICAL SCHEMATIC – CALIBRATION SYSTEM AND CLOCK FOR 6-INCH UV CAMERA

select assembly ("D"). Also shown are the associated elements which are the aperture plate ("A"), the calibration unit ("E"), the photographic unit ("F"), the photoelectric detector ("G"), and the image dissector tubes ID-3 and ID-4.

Several of the elements have more than one possible position. The aperture wheel may be indexed to 23 positions, 22 different sized apertures used for photometry, and one "clear" position (position 23) used with the other detectors. The mode select assembly has three positions; the "clear" position permits light to travel from the telescope image to the photometer, the "shutter" position permits light from the calibration unit to reach the transfer lens, and the "view" position uses a 45° mirror to direct light from the telescope image plane (with the aperture plate in the "clear" position) to the transfer lens. The detector select assembly has three positions: the "clear" position permits light from the transfer lens to pass directly to the photographic unit; the "ID-3" position uses a 45° prism to divert light from the transfer lens to ID-3; the "ID-3 and ID-4" position uses a beam splitter to send half of the light to ID-3 and a 45° prism behind the beam splitter to send the other half of the light to ID-4. The operation of the operation mode select system is summarized in Table I.

1. Detector Select and Mode Select Assemblies

The detector select and the mode select assemblies both contain optical elements mounted on slides which move on guide rails; the slides are driven by small d-c gearhead motors (Globe type 128A721-120 rpm) coupled to lead screws. No speed controls are used, the speed of movement is constant at approximately 0.2 inch per second. Micro switches are located at the various positions to send signals to the console indicating the status of each assembly; logic circuitry in the console analyzes the status signals and sends drive/stop commands to the two motors to position the slides to the proper positions as selected by the mode select switch on the console (Figure 18). Five indicator lights on the console indicate when the slides have been positioned for the operating mode selected. Note that more than one indicator light may be on at one time — for example, if the operating mode "CAL ID3/4" has been selected, lights CAL ID3 and ID4 will be on.

2. Transfer Lens

It is important that the optical relay system not degrade the image when it is transferred from the telescope image plane to the image

TABLE I

Operating Mode Select System

OPERATING MODE	FUNCTION	MODE SELECT POSITION	DETECTOR SELECT POSITION	SIGNAL SOURCE	TRANSFER LENS USED	APERTURE POSITION
P.E.	Photoelectric Photometry	Clear	—	Telescope	No	Selected Size
ID-3	Image Scan with ID-3	View	ID-3	Telescope	Yes	Clear
ID-3/4	Simultaneous Image Scans with ID-3&4	View	ID-3/4	Telescope	Yes	Clear
PHOTO	Photography of Field	View	Clear	Telescope	Yes	Clear
CAL 3	Calibrate ID-3	Shutter	ID-3	Calibration Unit	Yes	Clear
CAL 3&4	Calibrate ID-3&4	Shutter	ID-3/4	Calibration Unit	Yes	Clear
CAL PHOTO	Calibrate Photo	Shutter	Clear	Calibration Unit	Yes	Clear

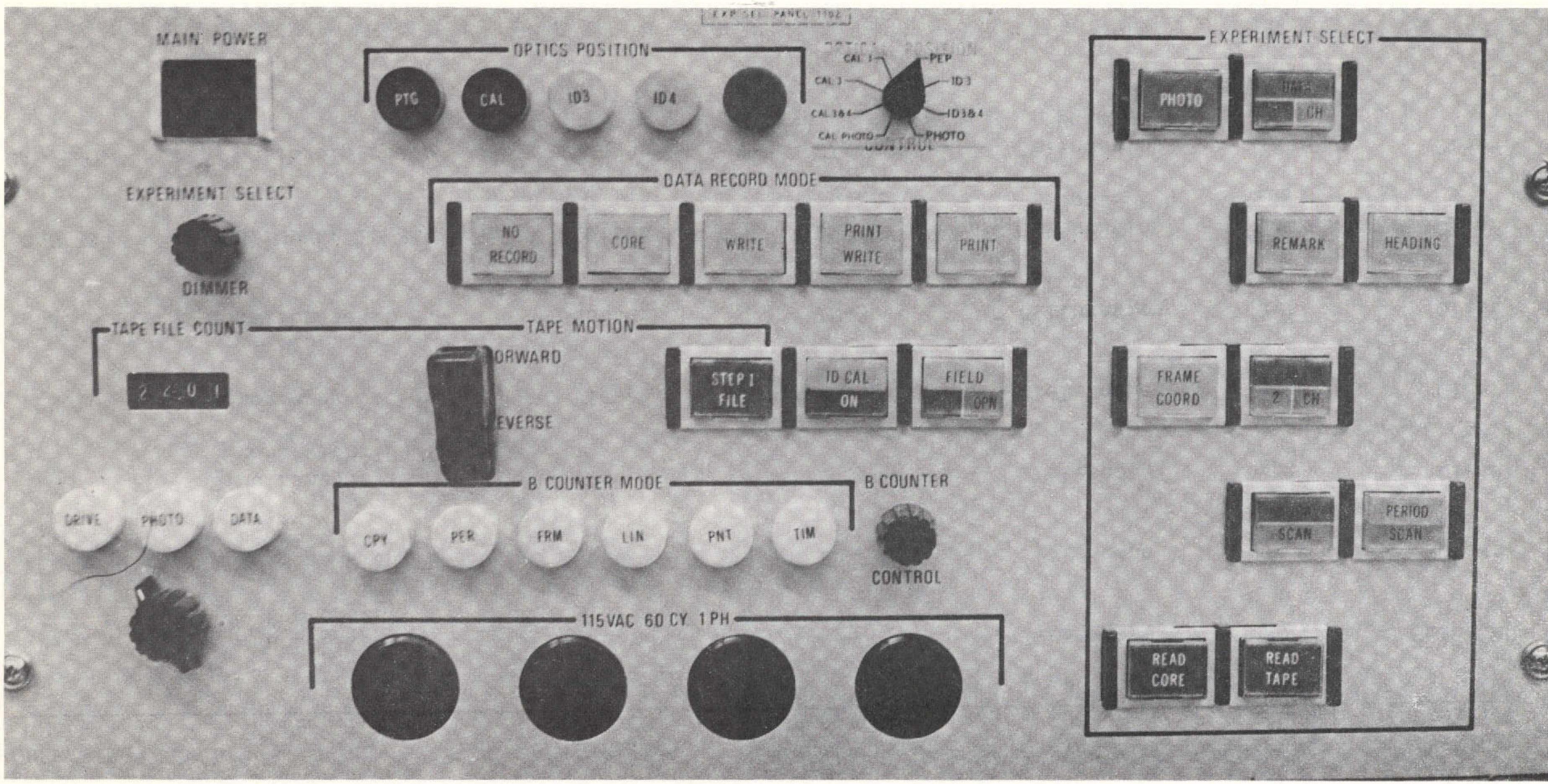


Figure 18: CONSOLE CONTROLS FOR DETECTOR SELECT AND MODE SELECT

dissector and photographic detectors. By far, the most critical element in the relay system is the transfer lens; a special lens was designed, with the assistance of the Optical Science Center, to meet the following design specifications:[5]

Magnification Ratio: 1:1.00

Field Size: 25.4 mm

Relay Distance: 400 mm

Resolution: 0.5 arc second on the 90-inch telescope (0.05 mm)

Wavelength: 3700Å to 1.0 micron

Light Transmission: Minimum of 90% over the wavelength range specified above.

Transverse Motion: Transverse Motion of ±3 mm (introduced by guidance signals – see Section II.A.3.e.) shall not upset the optical correction.

Physical Size and Weight: As small as practical, but in no case to exceed 50 mm diameter by 150 mm long and 0.5 pounds.

Maintenance: Shall require no adjustments after initial installation and alignment in the IDCADS system. Vibrations at up to 30 Hz and 10g shall not damage the unit. Dust on the surface elements shall not be reimaged at the new focal plane.

Ghost Images and Reflections: Shall be minimized.

Lens systems designed for use in the visible region (0.4μ to 0.7μ) are usually achromatic lenses (corrected for spherical aberration in one color of the spectrum and for axial chromatic aberration in two colors). However, such a lens has the chromatic aberration reduced to zero only at the two wavelengths selected for correction; at other wavelengths, appreciable chromatic aberration may remain. For the IDCADS system the spectrum is so broad (0.37μ to 1.0μ) that it was felt that an apochromatic lens would have to be used (corrected for chromatic aberration in three colors).

Apochromatic lenses usually have a material such as flourite (calcium flouride) for one or more of the elements. Flourite has a low refractive index, low dispersion, and a partial dispersion ratio different

[5] For more complete design information on the transfer lens, see Steward Observatory Report T 71-20, "A 1:1 Apochromatic Transfer Lens System," W. G. Tifft and R. A. Buchroeder, December 1, 1971.

from glass, so that a better simultaneous correction for chromatic aberration and spherical aberration can be accomplished by its use as a positive element in a lens system. Figure 19 shows the focus error-vs-wavelength characteristic for a normal achromat lens compared to that of the flourite apochromat designed for IDCADS.

The final design of the apochromat utilized a twin doublet, as shown in Figure 20. It would have been possible to design a comparable lens using an air spaced triplet. However, a triplet is sensitive to manufacturing and alignment errors and would have two soft flourite elements as the outside elements, subject to damage. The pair of cemented doublets is less sensitive to misalignment and has the flourite elements as internal elements so that they are protected from accidental damage. The dimensions, including the housing of black anodized aluminum, is 38 mm in diameter by 44.5 mm in length and weighs 0.26 pounds. The unit was fabricated to specifications by Herron Optical Company. Figure 21 shows spot diagrams of ray traces performed by the computer for on-axis and three field points; the circles on the diagrams represent a point 0.1 mm in diameter.

The image relay system incorporates a field lens which is mounted slightly outside the 90-inch focus at a distance of 157 mm in front of the relay lens. The field lens is a plano-convex lens made of UBK-7 glass, 30 mm in diameter, 6.0 mm thick, and with a radius of curvature of 100.0 mm; it is not mounted in the same housing as the transfer lens, but is part of the mode select assembly as was indicated in Figure 16.

e. Image Motion Stabilization (guidance)

The method of developing an error signal by detecting motion of a guide star as viewed by the guider tube (ID-1) was discussed in Section II.A.2.b. This error signal, after processing in the console, is returned to Module II to stabilize the image position as viewed by the data collectors. For the scanning image dissector tubes, ID-3/4, the error signal is electrically added to the deflection signals to maintain the apparent position of the image stationary. There is no equivalent electrical input point, however, which may be used to stabilize the image during aperture photometry or photography.

During photometry, image motion with respect to the photomultiplier is of little consequence since a Fabry lens is used ahead of the cathode to distribute the light uniformly over a large portion of the cahtode. However, it <u>is</u> important that the position of the image with respect to the

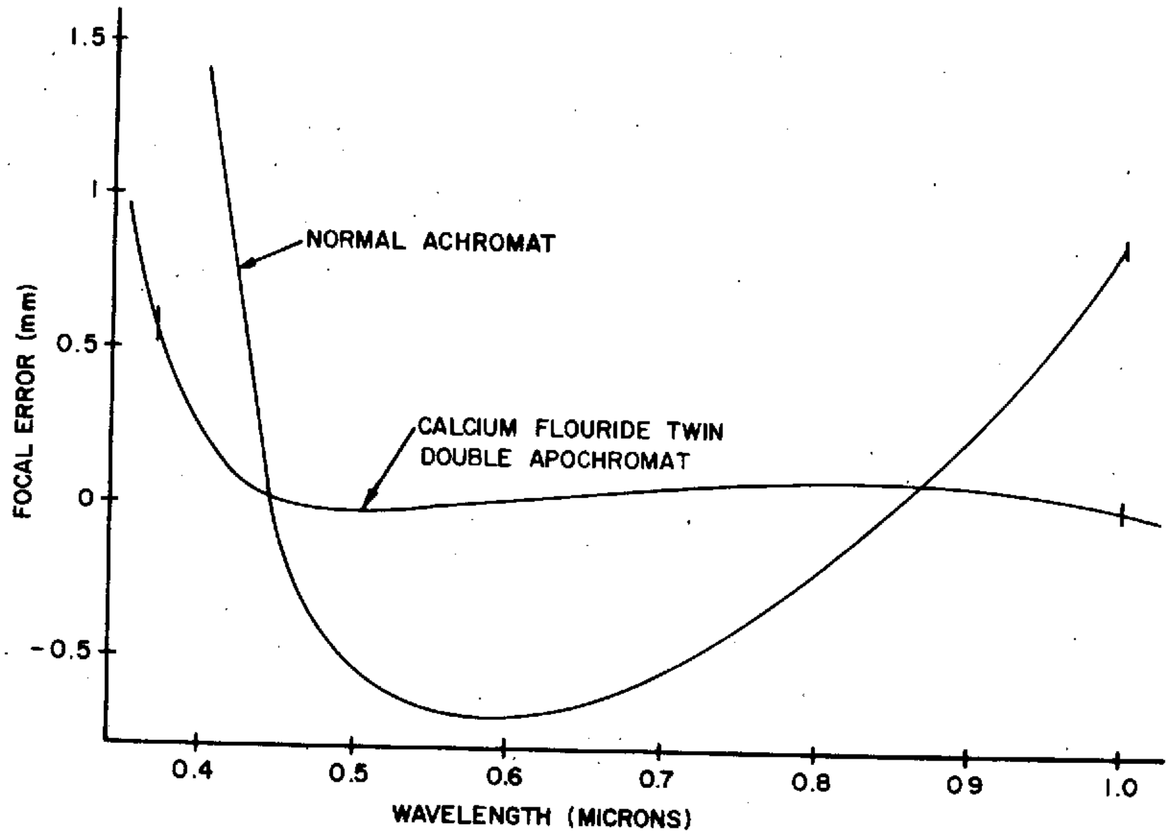
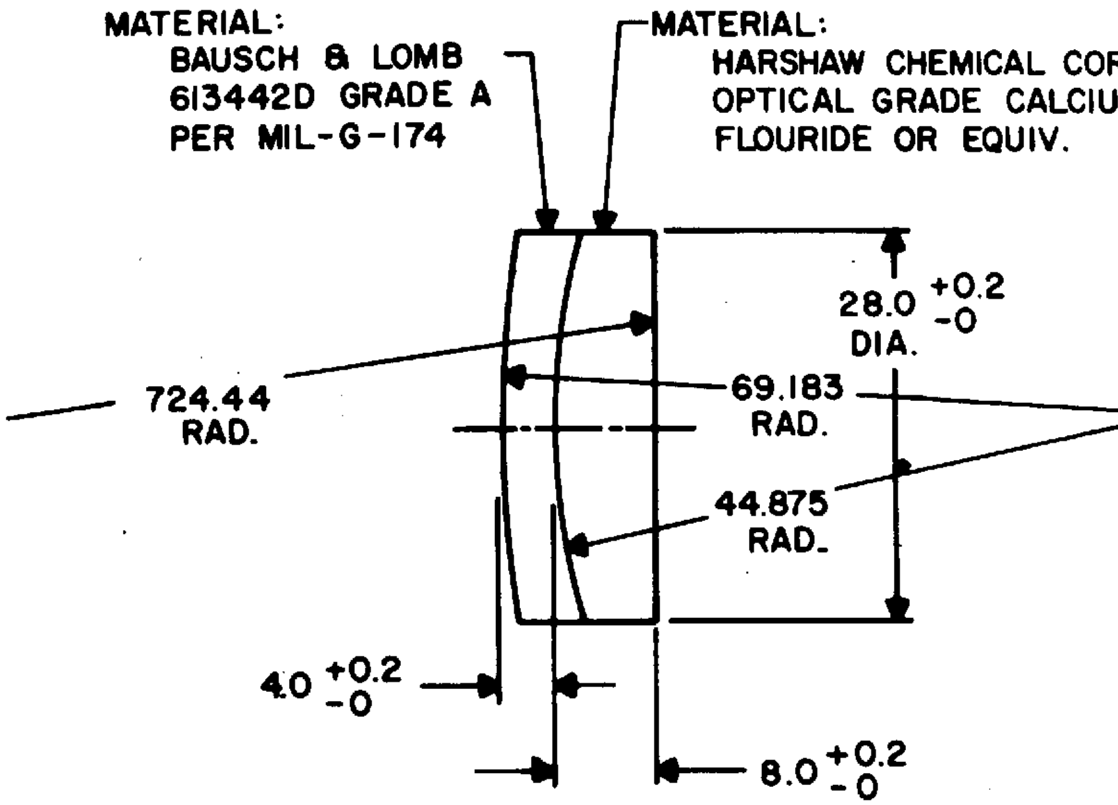


FIGURE 19 : FOCUS CURVE vs WAVELENGTH FOR RELAY LENS



(a) DOUBLET LENS (ONE HALF OF APOCHROMAT LENS)

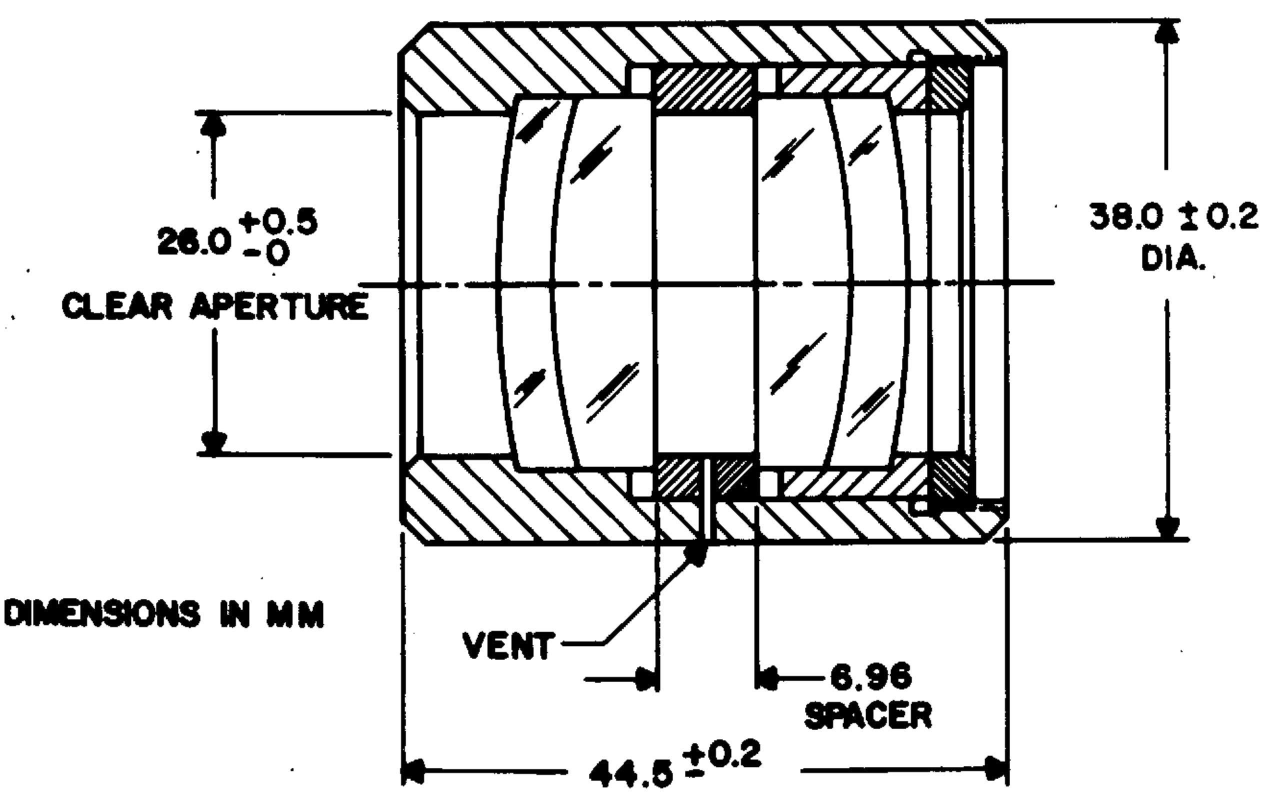


FIGURE 20 (b) RELAY LENS ASSEMBLY

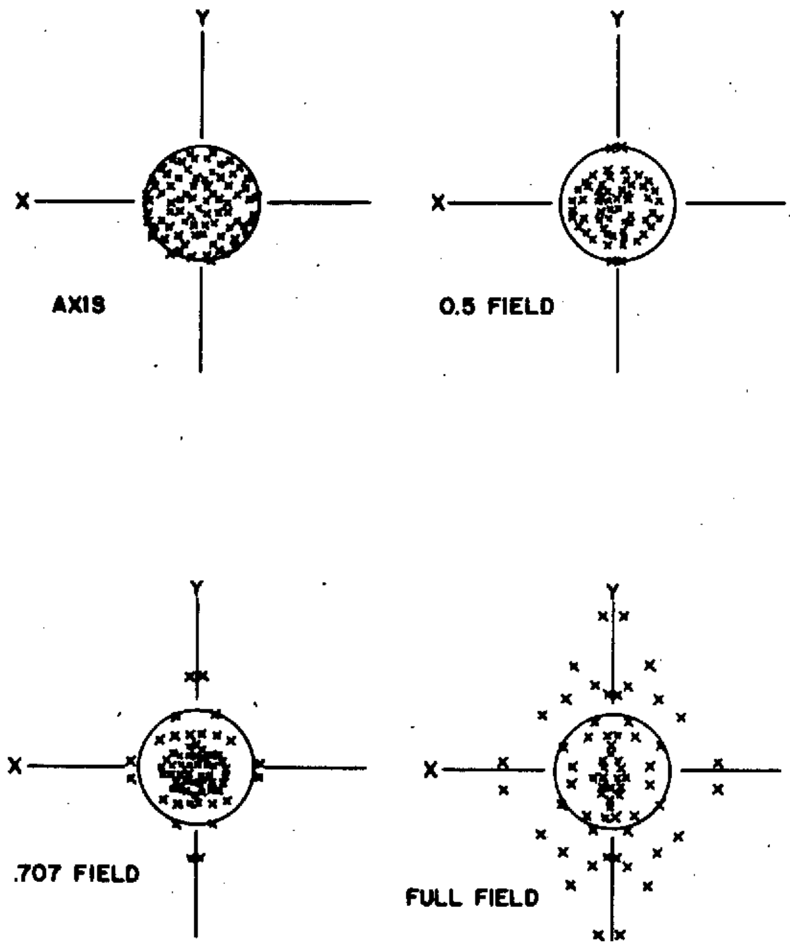


FIGURE 21 COMPUTER RAY TRACE SPOT DIAG. OF TRANSFER LENS.

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defining aperture remain constant; this is especially true if a small aperture is used so that little background is visible around the image. Under such conditions, any image motion with repect to the aperture may result in part of the image being obscurred by the aperture plate.

In IDCADS, the relative positions of the image and of the aperture are maintained constant by using the guidance signal to physically displace the aperture so that it tracks the image. This motion is obtained through the action of two armature/coil vibrator units (Ling Electronics type 203) which are coupled to the X and Y axes of the aperture plate. A schematic of the vibrator operation is shown in Figure 22. Two Ling 25 watt amplifiers (one for "X" motion, one for "Y") with differential inputs are located in the console. The error signal from the guider is fed to one input of the amplifier; the output of the amplifier drives the coil of the vibrator so that the armature moves and displaces the aperture plate. A linear displacement transducer (Columbia differential transformer type M-150-S3R), which is mechanically coupled to the armature, develops a signal proportional to distance moved; this signal is fed back to the outer input of the amplifier so as to subtract from the error signal, reducing the input to the amplifier. This position feedback permits the use of high gain for the amplifier so that the response of the vibrator is very rapid and is quite "stiff" (insensitive to changes in orientation which change the ambient g-load on the vibrator). If an integrator were included in the feedback loop, it would be theoretically possible to drive the differential error signal to zero; however, the high loop gain in the existing system reduces the effective error to an insignificant amount so that integral control, with its attendant instability problems, was not required.

The vibrator used is capable of developing 6 pounds of thrust, has a maximum excursion of ±0.1 inch, and a frequency response of 0 to 10 kHz. The maximum rate of image motion expected is 30 Hz; at that frequency, the vibrator can displace the 0.75 pound load of the aperture plate the full 0.1 inch (acceleration equal to 10 g, maximum force required 6 pounds).

For the photographic mode of operation another set of vibrators is used to displace the transfer lens (see Figure 23) to match image motion so that the photographic image remains stationary. (Only one set of power amplifiers is required, since the photographic mode and photometry mode will never be used simultaneously.)

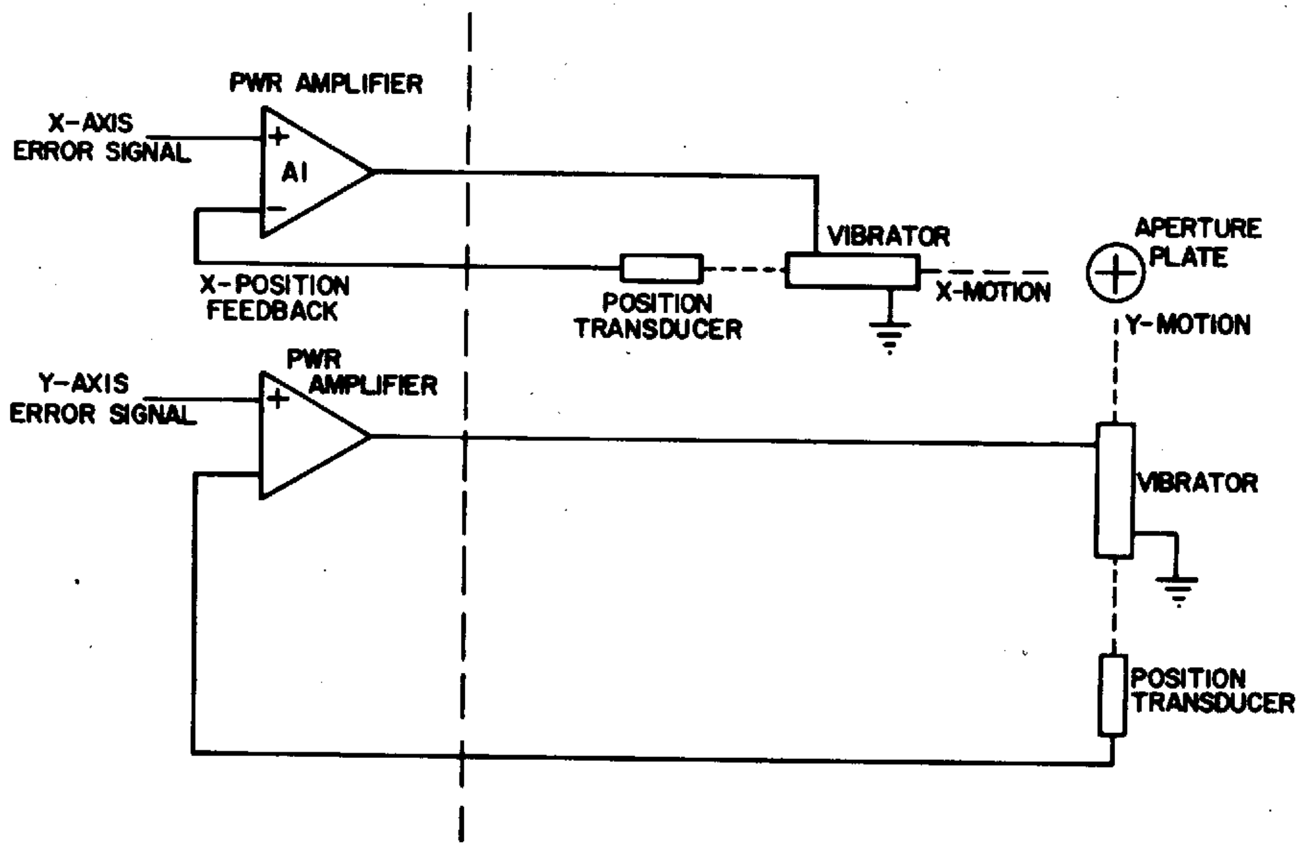


FIGURE 22 SCHEMATIC OF IMAGE MOTION COMPENSATION WITH VIBRATOR

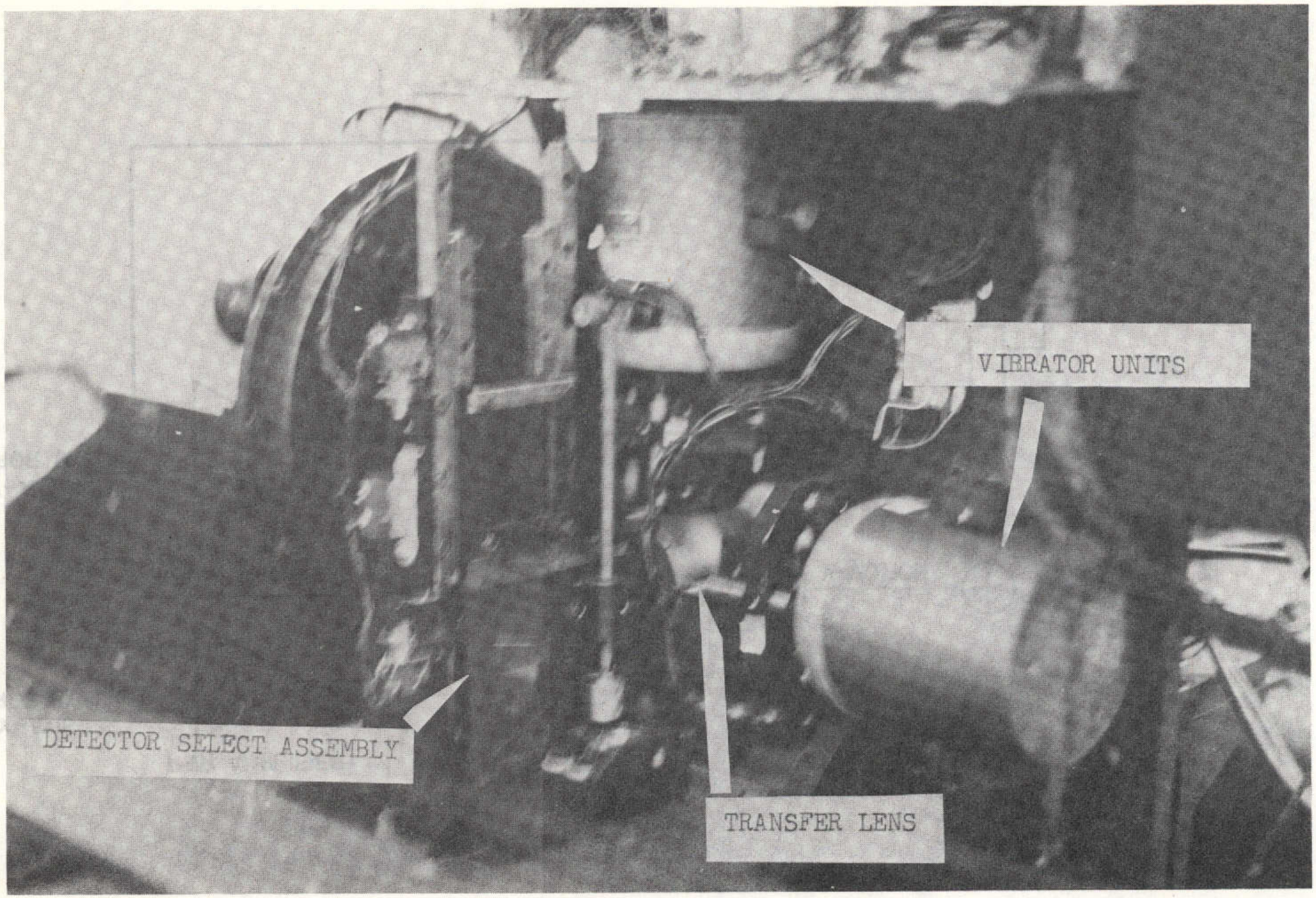


Figure 23: VIBRATOR UNITS ATTACHED TO TRANSFER LENS

f. Signal Processing Unit

The signals from the image dissectors and photoelectric cell are routed through the Signal Processing Unit (see Figure 3) before being sent to the control console. Figure 24 is a schematic diagram of how the signals are processed.

The output signal at the anode of a photomultiplier used in the photon counting mode consists of a series of narrow pulses (typically 30 nanoseconds wide); the pulses are developed from "captured" photons which release a cathode electron or from noise generated in the tube. The design of a suitable preamplifier which will amplify the narrow signal pulses without excessive pulse stretching and which will discriminate against the noise pulses is an involved and tedious job; since the preamplifiers used in IDCADS are complicated solid-state electronic units, a complete description of them will be included in Volume II. For the purposes of this discussion, it is sufficient to say that the preamplifiers have two output modes. A "pulse" output mode consisting of narrow (50 nanoseconds) pulses is for use in photon counting with targets having faint light levels. As the target becomes brighter, the photon count increases and the probability of missing a significant number of counts because of overlapping pulses becomes higher. At a count rate of around 10^5 per second (corresponding to a magnitude 12 star with the 90-inch), it is desirable to switch to a "dc" mode in which the output of the preamplifier is a current proportional to the average photon rate. A photomultiplier with a gain of 10^6 will have an anode current of approximately 10^{-8} amperes for a detection rate of 10^5 photons per second; this current may be fed to a high resistance (10^8 ohms) to develop a signal level of one volt. This dc voltage may in turn be fed to a voltage-to-frequency converter which develops a frequency closely proportional to input voltage, so that the same counting techniques which are used for data analysis in the photon counting mode may be used in the dc mode.

The voltage-to-frequency converters are Anadex type 1700-5044-00, which have an input range of 0 to 10 volts for an output frequency of 0 to 10^6 Hz and a linearity/stability of 0.05%. The output of the converters or the pulses in the pulse mode are sent through pre-scalers which on command will divide the count by a factor of 1, 10, 100, or 1000. This is to prevent the count rate from exceeding the rate capability of the counters in the console (3mHz) in the case of very strong signal, or the total count capability (10^6 counts) in the case of long sample periods. The output of the

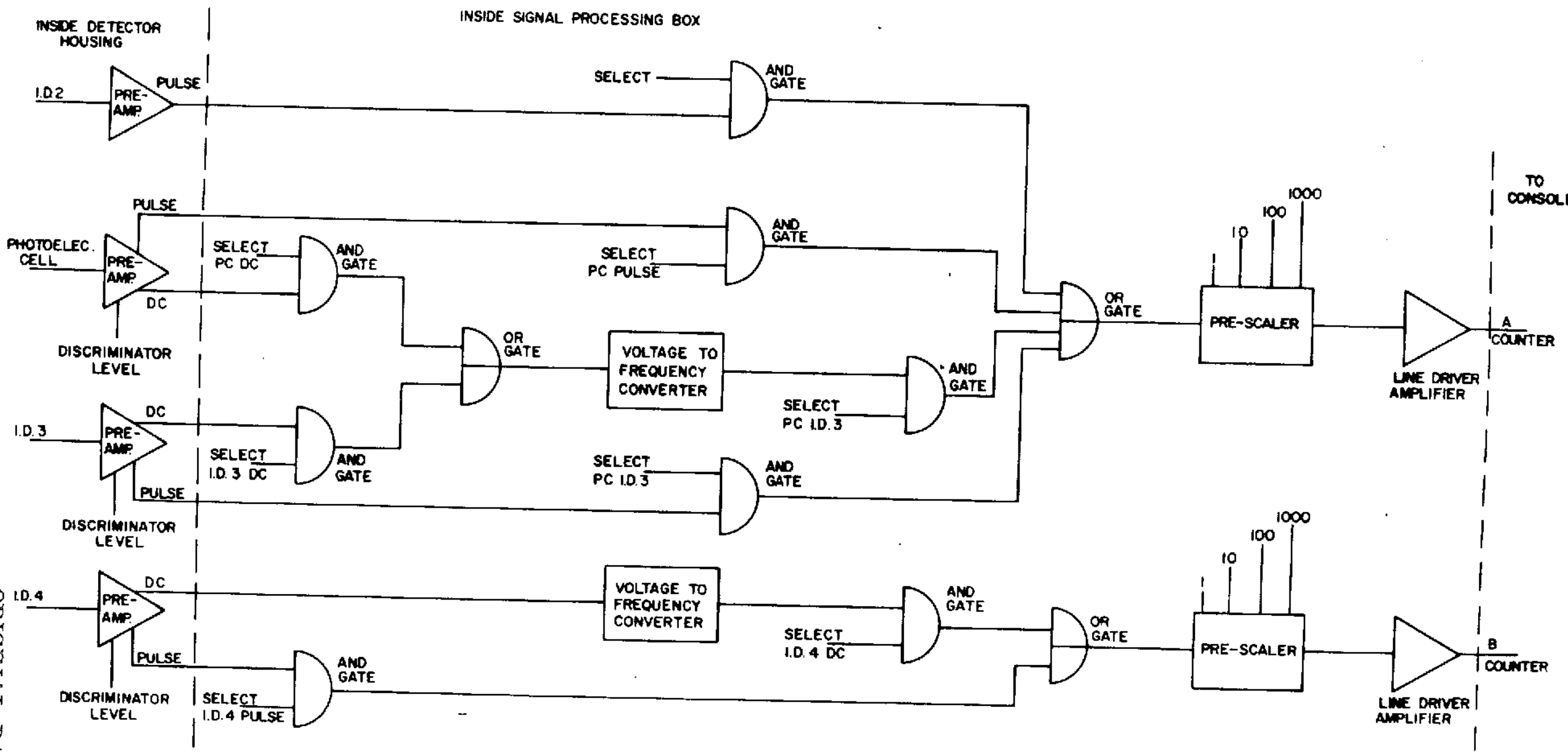


FIGURE 24 SCHEMATIC OF SIGNAL PROCESSING UNIT

pre-scalers drives line amplifiers which match the signal to the 50 ohm coaxial cable going to the console.

Logic gates are used to select and route the desired signals as determined by the operating mode selected at the control console. The functions indicated in Figure 24 are performed by six circuit boards (each approximately 3"x4") contained in the signal processing box: two voltage-to-frequency converters, two pre-scalers, one board containing the logic gates, and one board containing the two line drivers.

B. Other Instrumentation Packages

As was discussed in Section I, the IDCADS console may be used with other instrumentation packages for specialized applications.

1. Simplified Telescope Package (Module III)

Figure 6 was a photograph of the simplified instrumentation package (Module III). It is intended to permit the use of the IDCADS image scan system with telescopes other than the 90-inch, or for specialized observations on the 90-inch.

For use with the 90-inch, Module III fits on the same adaptor plate and ring gear assembly as the regular telescope instrumentation package. This was done primarily from an economy standpoint — since an adaptor plate was required anyway, use of the existing plate would prevent duplication. This does have the added advantage of permitting the use of the Theta drive and read-out subsystem while Module III is on the 90-inch; however, data acquisition with Module III is normally done at the center of the telescope field of view, so that the addition of a rotational coordinate is of limited benefit.

The data acquisition unit (which contains two detector devices — an eyepiece and an image dissector tube) mounts on a pair of precision-ground and hardened guide rails, similar to the rails used on Modules I and II except that the smaller weight of Module III permits the use of 1.000-inch diameter rails rather than 1.250-inches. Three-point suspension with Thompson linear ball bushings insures rigid mounting and permits positioning by a precision lead screw and ball bearing bushing. Positioning is accomplished by turning the lead screw with either a handcrank or by actuating a small electric motor (Bodine type NS1-12RA1 with integral 6:1 gear head reduction); the reduced motor speed of 290 rpm turns the 6-pitch lead screw so that the data acquisition unit is moved at a rate of approximately 1 inch per second.

One end of the data unit contains the eyepiece, a Jaegers Wide Angle type 1E1405 (1.5-inches diameter, four element compound lens) fitted with cross hairs. In operation, the movable carriage is moved all the way to one end so that the eyepiece is at the center of the assembly. The telescope pointing angle is adjusted until the object of interest is centered on the cross hairs. The movable carriage is then moved to the limit of its travel in the other direction. Limit stops and switches have been adjusted during calibration so that the object of interest (center of field of view) is now near the center of the cathode of the image dissector. By operating the scan controls on the console and viewing the field scanned by the image dissector on the viewing oscilloscope of the console, the object of interest is detected and may be centered in the field of view by making fine adjustments to the telescope pointing angle. Data scans may now be taken by proper operation of the console controls.

Note: See Section I.B.1. for operation of scan controls. Although detailed area scans may be obtained, the versatility of Module III is limited as compared to the regular telescope unit in that: (1) no automatic guidance is provided, (2) no aperture photometry or (3) photographic data may be obtained, and (4) simultaneous double detector scans may not be made.

The ID tube is "borrowed" from the regular telescope unit (normally ID-3), complete with the filter wheel, shutter, and preamplifier. A separate signal-conditioning box is mounted on Module III, with sockets available for four plug-in printed circuit boards — a Logic Gate card, a Voltage-to-Frequency Converter, a Prescaler Divider, and a Line Driver Amplifier. Figure 25 is a block diagram schematic showing the operation of the signal conditioning unit. Signals from the ID tube, in either pulse or dc form, are brought into the signal box; the method of operation (pulse or dc) is selected by the logic gate card (which is controlled from the console); in the case of dc operation, the dc signal is converted to a 0 to 100 kc frequency by the V-to-F converter; the output from either the V-to-F converter or the ID pulses are directed to the prescaler, where the count rate may be divided by any decade factor from 1 to 1000; the output from the prescaler goes to the line driver amplifier, which sends the signal via coaxial cable to the A+ input channel of the console.

For operation with telescopes other than the 90-inch, Module III is attached by means of an adaptor plate designed specially for the telescope being used. In most cases the adaptor plate may be quite simple. Figure 26

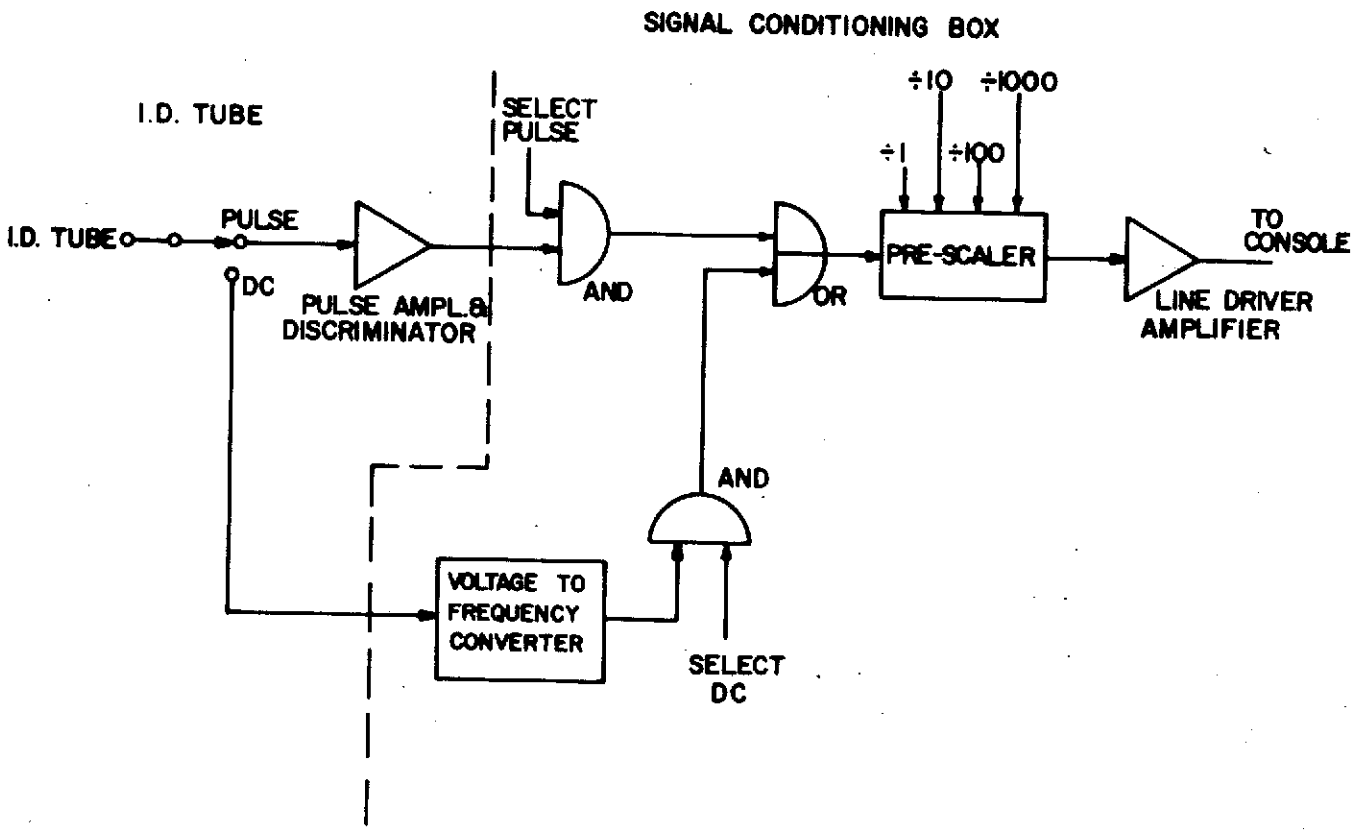


FIGURE 25 : SIGNAL CONDITIONING BOX FOR MODULE III

shows the dimensions of Module III; the adaptor plate must attach to the telescope, using whatever mounting holes that may be available, and provide for mounting Module III to the adaptor plate. There are six holes (clearance holes for 3/8" bolts) for attaching Module III to the adaptor plate arranged on two sectors of a bolt circle 26.5 inches in diameter and spaced 20° (4.625 inches) apart.

The focal plane for the eyepiece and the ID tube on Module III is one inch above the base of Module III; the adaptor plate should have the proper thickness so that the range of focus of the telescope will permit focusing of the telescope image at that plane. The portion of the field of view which may be "viewed" by either the eyepiece or the ID tube is a strip 1-inch wide by 16-inches long across the center of the telescope field. However, Module III is normally operated with the object of interest at the center of the field of view, since a circle approximately 1-inch in diameter at the center of the field is the only portion of the field which can be viewed by both the eyepiece and the ID tube (without changing the pointing angle of the telescope). Module III has a height (not including the adaptor plate) of 13 inches.

2. Plate Scanner

Figure 7 in Section I.D.2. was a photograph of the Plate Scanner instrumentation package which may be used with the IDCADS console. The principle parts of the plate scanner are shown in the schematic of Figure 27. The photographic plate to be scanned is placed on the plate holder inside the light-tight box. The plate is positioned on the plate holder so that the region of interest is over the 0.25-inch scanning aperture. Note: The 0.25-inch area is the only area on the plate which may be scanned without repositioning the plate. The light-tight box is 16 inches square, with the scanning aperture offset from center at a position 6 inches from each of two sides, so that any portion of a plate up to 12x12 inches may be scanned. The plate holder is fastened to a precision X-Y table (Automation Gages 4"x3.75") which has micrometer adjustments in the X and Y directions. This permits delicate, zero backlash position control so that the object of interest on the photographic plate may be centered.

Light from a uniform diffuse light source illuminates the area of the plate to be scanned. The light source consists of a 4-inch diameter hollow copper sphere which contains an 18-watt, 6-volt light bulb (G.E. type 1493); the inside of the sphere is coated with magnesium oxide (obtained by

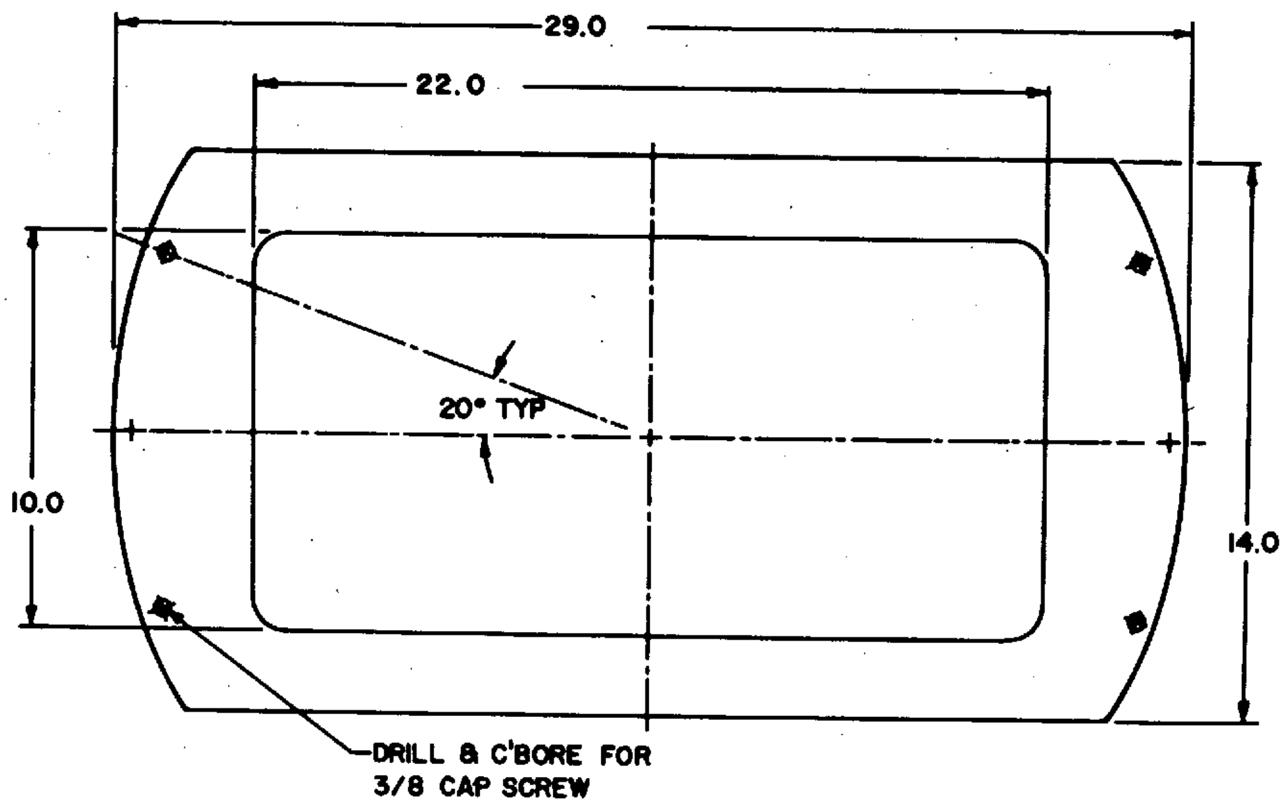


FIGURE 28 MODULE III BASE PLATE DIMENSION

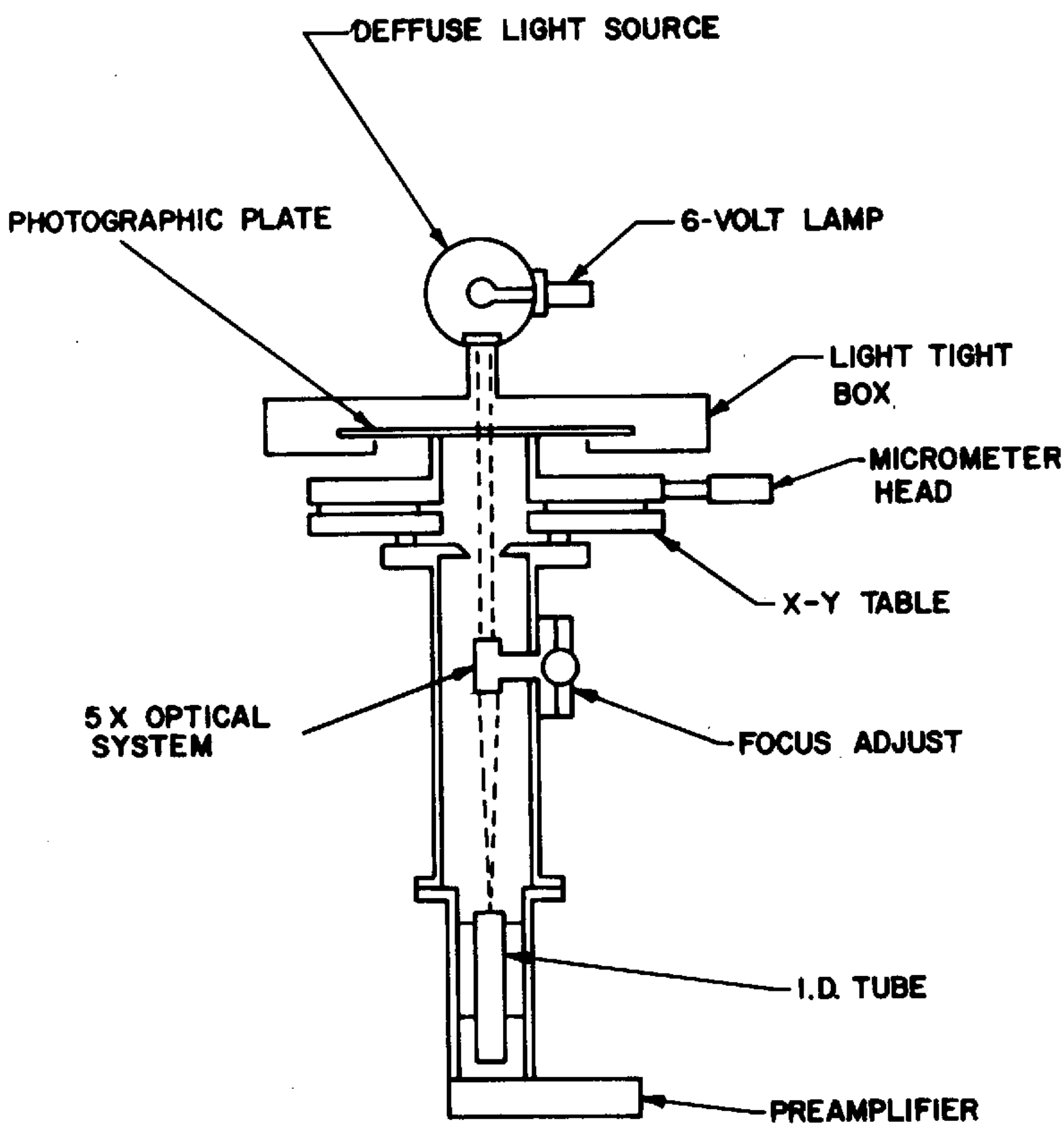


FIGURE 27 FUNCTIONAL SCHEMATIC OF PLATE SCANNER

burning a strip of magnesium inside the sphere); this coating serves as a highly reflecting diffuse surface, so that light bouncing around the inside of the sphere tends to become uniformly distributed through the sphere. Light to illuminate the plate emerges through the 1-inch diameter exit hole at the bottom of the sphere; an Opal diffusing glass plate covers the exit to further insure a diffuse light source. The lamp is supplied from a regulated 0-5.5 volt dc power supply (Elasco LIC 5-7A), which tends to provide a stable light intensity and permits adjustment of that intensity. A manually operated shutter blocks off the scanning aperture when in the "Off" position. The inside of the plate-holding box is coated with 3M Black Velvet paint to reduce reflected light.

When the shutter is open, the light passes through the area of interest to an optical relay system which reimages the photographic image onto the cathode of the image dissector tube with a X5 increase in image size. The ID tube, complete with preamplifier but without the filter wheel and the remote control shutter mechanism, is "borrowed" from the regular telescope instrumentation package. The plate scanner is connected to the console by a special 8 conductor cable which contains the control wires for the image dissector and the power for the preamplifier, a coaxial cable for the signal output from the amplifier, and a high voltage coaxial cable for the ID tube. These cables are all less than 15-feet long, so that noise and ground-loop problems tend to be minimized.

After power is supplied from the console, the light source turned on, and the manual shutter opened, the scan controls on the console may be operated so that scans may be made of the area of interest on the photographic plate. The viewing oscilloscope on the console may be used to make certain that the proper area is being scanned; then area scans may be made as with the telescope instrumentation packages.

3. Lunar Experiment Package

A brief description of the lunar experiment package was given in Section I.D.3. No further description of this unit will be made in the report because of the very complete description available in the Space Astronomy Report No. A 71-6, FINAL TECHNICAL REPORT OF NASA GRANT NGR 03-002-153, June 30, 1971.

C. Interconnections Between the Instrumentation Packages and the Control Console

In order to perform all of the functions required between the control console and the primary instrumentation package, such as power supplies; telescope control parameter selection, monitoring, and adjustment; signal conditioning and monitoring; instrumentation package orientation; plus safety interlocks, etc., a large number of interconnections between the IDCADS console and the telescope instrumentation package are required. If all of the data analysis systems were simultaneously connected (ID scans, aperture photometry, and photography, with automatic guidance), a total of some 216 signal and control wires, plus 5 coaxial signal cables and 5 high-voltage coaxial cables would be required. This would result in a very large and cumbersome cable connecting the console and the instrumentation package; such a cable would not only be difficult to store, transport, and connect, but might add serious unbalance problems to the telescope since the cable position would necessarily shift as the pointing angle of the telescope was changed.

In order to simplify the interconnection problem, it was decided to utilize a cable already installed in the telescope during manufacture. This cable runs from a junction box on the pedestal of the telescope, up through the fork of the telescope, through the rotating joint at the tube, and terminates at a junction box mounted on the outside of the telescope tube near the Cassegrain focus. However, this cable contains only 135 #22 control wires, 3 #10 power wires, 2 signal coaxial cables, and 1 high voltage coaxial cable, insufficient to handle all of the requirements of the IDCADS system. An analysis was made of the interconnection requirements, and it was determined that no more than 108 #22 control wires are required continuously during all phases of the IDCADS operation. These include such functions as the R-θ drive and position readout; power supplies; shutter control lines; R_1, R_2, and view-guide assembly drives; and status indicators and safety interlocks.

Of the remaining 108 control wires, it was found that 24 of them (the wires from the telescope "Paddle" to control the position of the telescope) did not have to run all the way to the telescope tube, but could terminate at the Coude' station near the telescope pedestal. This left 84 control wires which are required only during certain modes of operation. Although the IDCADS system has a great number of possible modes of operation when all of the permutations of detector choice, data analysis method, etc. are considered, it was determined that for multiplexing purposes the system could be considered as having 5 different modes of operation. Providing control wires for each mode was not the elementary task of dividing the 84 functions into five more-or-less equal groups, however, since some of the functions are required for two, three, or even four of the modes of operating.

A logic decoding network is incorporated in the control console which analyzes the mode of operation selected and activates one of five 36-contact relays. The activated relay selects up to 27 of the 84 functions to be multiplexed and routes these functions through the telescope cable to the instrumentation package on the telescope; there, one or another group of five identical relays is activated to route the functions selected to the correct portion of the experiment package. (Note: For a complete description of the multiplex system see Volume II. See, also, the Appendix for a schematic diagram #9.)

A maximum of four signal coaxial cables is required for any mode of operation (A counter, B counter, View, and Guidance) so that two external coaxial cables are required in addition to the two available in the internal telescope cable. Since four high voltage coaxial cables may also be required, with only one available, three external coaxial cables are run for this purpose. The resulting bundle of five coaxial cables is small and light enough so as not to create telescope unbalance problems.

The resulting cabling arrangement for the use of IDCADS with the primary instrumentation package on the 90-inch telescope is shown in Figure 28. Table 2 provides a listing of the number of conductors and the type of connectors used for each cable. See Section V.C. for a complete Wire Running List.

TABLE 2

Summary of Connections Between IDCADS and 90-inch

CABLE	FUNCTION	CONDUCTORS	CONSOLE TERMINATION	PEDESTAL TERMAINATION
C-1	Control	58 #22	P15 (SP06A-24-61P)	P10 (SP06A-24-61S)
C-2	Control	50 #22	P16 (SP06A-22-55P)	P11 (SP06A-22-55S)
C-3	Control (Multiplex)	27 #22	P17 (SP06A-22-32P)	P12 (SP06A-22-32S)
C-4	Power	3 #10	P18 AH&H Twistloc, 20A (Male)	P13 AH&H Twistloc, 20A (Female)
C-5	Telescope Control	24 #22	P19 (MS3106-24-28P) Cannon	P14 (67-06P18-24S) Amphenol

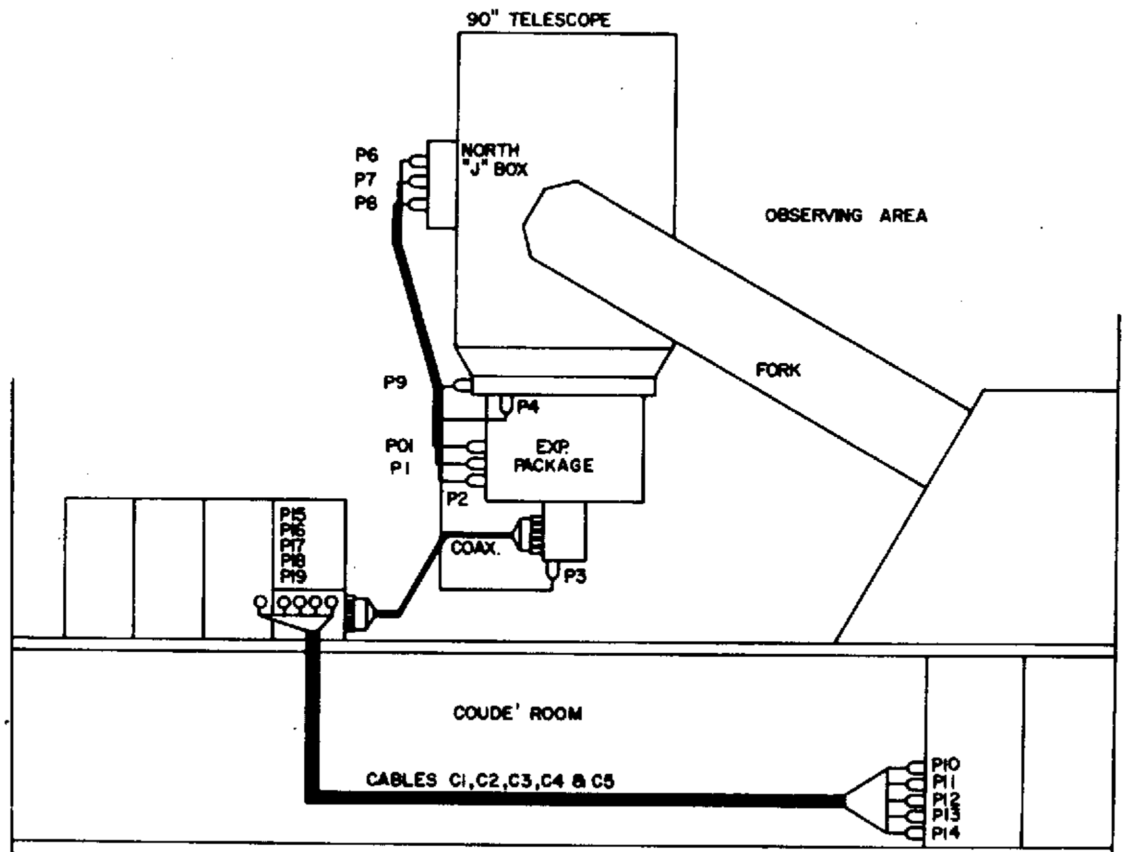


FIGURE 28 : INTERCONNECTION DIAGRAM BETWEEN IDCADS & TELESCOPE

TABLE 2 - con't.

Connectors on Experiment Package Harness, H-1

EXPERIMENT PACKAGE TERMINATIONS		TELESCOPE JUNCTION BOX TERMINATIONS	
Plug	Conductors	Plug	Conductors
P1 (SP06A-18-61S)	61 #22	P6 (SP06A-24-61P)	58 #22
P01 (MS3106-16-19S)	4 #22	P7 (SP06A-22-32P)	50 #22
P2 (MS3106A-28-21P)	37 #22	P8 (SP06A-22-32P)	27 #22
P3 (MS3106A-20-19S)	3 #10	P9 AH&H Twistloc, 20A (Male)	3 #10
P4 (SP06A-24-61S)	50 #22		

Different cabling systems are required for connecting the IDCADS console to the Module III simplified instrumentation package, the plate scanner, or to the lunar experiment package. A diagram of these connections is shown in Figure 29.

For use with Module III on the 90-inch telescope, the same cables between the IDCADS console and the telescope pedestal are used as for the regular instrumentation package. However, a different harness, H-2, is used between the junction box on the telescope tube and the instrumentation package, as is shown in Figure 29a. There are only two connectors used on the Module III package; one, P4, goes to the Theta drive and position readout the same as the regular package; the other, P1(III) is a 37 pin connector carrying the control and monitoring wires required by the single ID tube used in Module III. The signal coaxial cable and high-voltage coaxial cable required may be accomodated by those available in the telescope harness.

For use of Module III with telescopes other than the 90-inch, a separate cable is run from the console to the instrumentation package (Figure 29b). No Theta drive and readout is provided, so that a single 37 conductor cable going to P1(III) is sufficient. External coaxial cables are used.

For operation with the plate scanner, a single 13 conductor cable connects the console to the scanner (Figure 29c). Separate signal and high-voltage coaxial cables are provided. The cables for the plate scanner are quite short, which helps to reduce noise pick-up and ground loop problems.

For use with the lunar experiment package (Figure 29d), still another cable is used, with a single connector on each end.

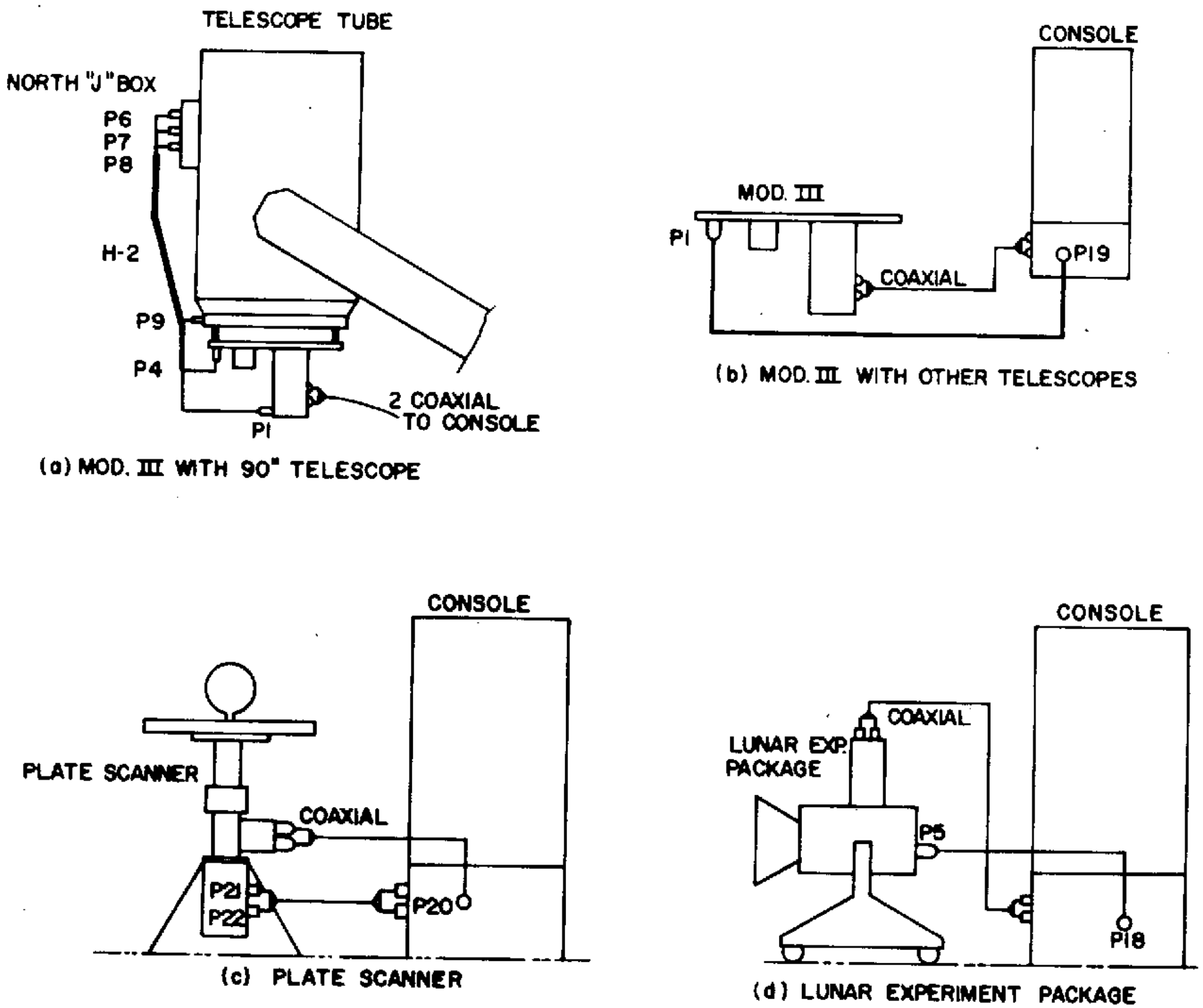


FIGURE 29 : CONNECTING CABLES BETWEEN IDCADS CONSOLE AND OTHER UNITS

Table 3 shows the characteristics of these various cables, and the Wire Running List (Section V.C.) lists the destination and function of each individual wire.

TABLE 3

Connections Between IDCADS Console and Other Experiment Packages

CONNECTOR	TYPE	CONDUCTORS
P1(III)	MS3106A-28-21P	37 #22
P4	Same as for Primary Instrumentation Package	
P6		
P7		
P8		
P9		

Module III with Other Telescopes

CONSOLE CONNECTOR	TYPE	MODULE III CONNECTOR	TYPE	CONDUCTORS
P19	MS3106-28-21P	P1(III)	MS3106-28-21P	29 #22 8 #10

Plate Scanner

CONSOLE CONNECTOR	TYPE	SCANNER CONNECTOR	TYPE	CONDUCTORS
P20	MS3106A-20-33P	P21	SLE-4P-JTC (Winchester)	4 #22 4 #22
		P22	SLE-7P-JTC (Winchester)	7 #22

Lunar Experiment Package

CONSOLE CONNECTOR	TYPE	EXPERIMENT PACKAGE CONNECTOR	TYPE	CONDUCTORS
P18	MS3106A-36-10P	P5	SP06-22-32S	48 #22

III. CALIBRATION, ALIGNMENT, AND INSTALLATION PROCEDURES

Since IDCADS is a highly complex system capable of making measurements with a high degree of accuracy and resolution, it is important that the system be calibrated, adjusted, and aligned with care a precision. Many of the adjustments may be interacting to some extent, so that iterative procedures may be required to reach the precision specified. The entire calibration and alignment procedure will take many hours to perform; however, all procedures are semi-permanent in nature and will not need to be repeated unless components are removed for modification and/or repair and then replaced, or unless the equipment operation indicates that some lock nut or set screw has loosened, permitting an adjustable parameter to shift.

A. Equipment Required

Most of the equipment required for calibration, such as power supplies, oscilloscope, and digital voltmeter, are built into the console for use during normal operation. However, the following items are not a regular part of the system and must be provided separately:

(1) A test stand. Although theoretically all calibration could be performed with IDCADS mounted on the 90-inch telescope, for practical reasons it is necessary to have a test stand supporting the instrumentation unit in the laboratory so that it may be connected to the console, power supplied, and "normal" operation (using simulated stars, etc.) obtained. The test stand used in the Space Astronomy laboratory may be seen in Figure 3 on page 6. This test stand holds the instrumentation unit securely (in an "up-side-down" position so that the various components are easy to work on); a simulated star may be mounted in the base of the stand, and the unit may be connected to the console for complete simulated operation.

(2) A simulated star. Must be capable of producing a "star" of variable intensity with a diameter not to exceed 0.005 inch. The star image must be formed at least ten inches in front of the simulator (on the Z axis). Provision must be made for positioning the star along the other two orthogonal axes (X and Y) with a minimum distance of travel of one inch and with a precision of positioning to within 0.001 inch. A schematic of the simulator used in the laboratory is shown in Figure 30; it consists of a 6-volt lamp bulb illuminating a pin hole, an optical system for reimaging the pin hole ten inches in front of the simulator, and a 2-axis X-Y table (Automatic Gages 3.75"x4.0") positioned by micrometers which indicate position to 0.001 inch over a range of travel of 1.0 inch in each axis. The intensity of the star is varied by changing the voltage supplied to the lamp.

(3) A dial indicator. Capable of at least one-inch travel and with a position readout to within at least 0.001 inch. The indicator used in the laboratory is a Starett type 1481, which has a three-inch

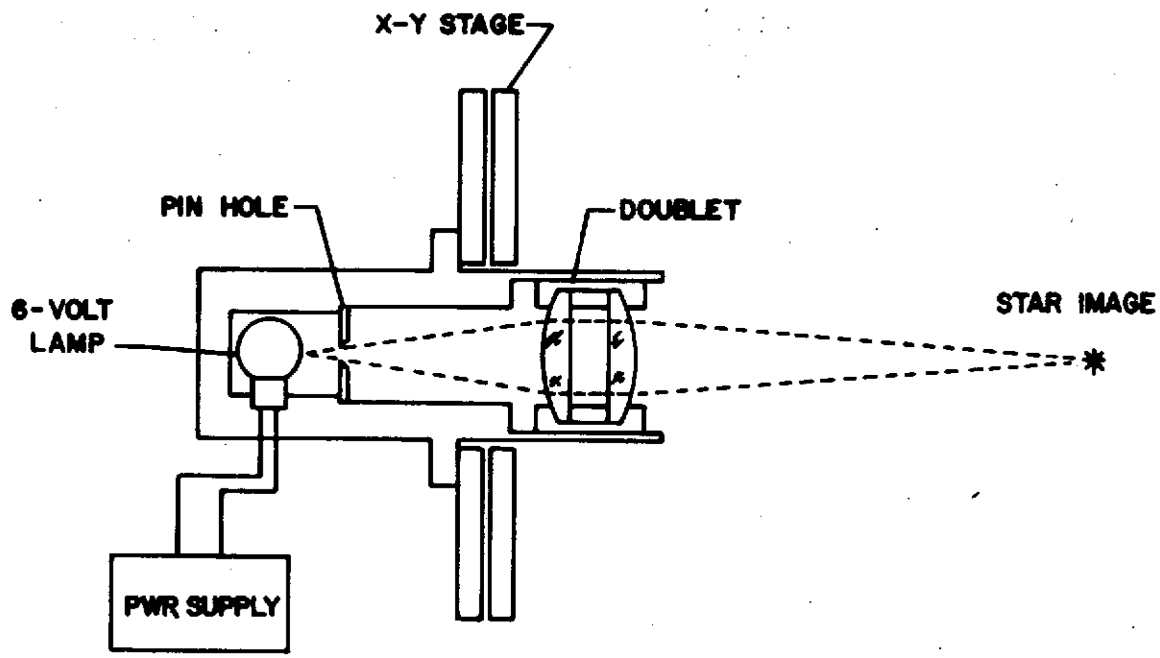


FIGURE 30 STAR SIMULATOR

travel and a three-inch dial which indicates position to within 0.005 inch.

(4) Portable VOM, such as a Simpson Model 260, and a portable oscilloscope.

(5) A tool chest. To be stocked with a complete assortment of screwdrivers, box wrenches, Allen wrenches, C-clamps, etc.

B. Calibration and Alignment

Most of the calibration and alignment procedures for the instrument unit are mechanical or electro-mechanical in nature. When making mechanical adjustments, care should be exercised to insure that smooth bearing surfaces are not marred by the use of improper tools or contaminated with dirt, finger prints, etc.

1. Adaptor Plate and Ring Gear

There are two quantities which must be adjusted on the adaptor plate and the ring gear — the Theta Angle readout, and the Phasing of the Coordinate Transformation circuit for the guidance signals.

a. Theta Readout

This quantity must be adjusted with the adaptor plate, ring gear, and instrumentation unit mounted on the 90-inch telescope. (See Section III.B.1. for the procedure for mounting.) The console-to-telescope cables must be connected and the <u>Console Power</u> ON. With the telescope pointed near the zenith, activate the <u>Theta Drive</u> control on the console and rotate the instrumentation package until the guide rails on which Modules I and II are mounted run in the East-West direction, with Module I at the geographic East end of the rails. The East-West direction is determined by following a star drifting across the field of view.

<u>Criteria</u>: The Theta Angle readout on the console must indicate 270.00 ± 0.15 degrees.

If this condition is not met, loosen the set screws attaching the drive gear to the Theta Encoder and rotate the shaft of the encoder until the reading is within tolerance. Make sure that the idler wheel is adjusted so that there is no slack in the timing belt. Retighten the set screws and check the angle indication to confirm that it has not shifted. Activate the Theta drive and rotate the instrumentation unit until the angle readout indicates 000.00 degrees. Module I should now be at the geographical South position (telescope North). If it is not, either the timing drive belt has slipped or there is a serious malfunction in the system. As further checks, Module I should be at geographical North when the angle indication is 180.00 degrees and at geographical West when the angle indication is 90.00 degrees. Check to see that the limit stops on the Theta drive cut off the drive signal at approximately 330° when rotating in a CCW direction (increasing Theta reading) and at approximately 315° in the CW direction, and that the cable harness remains free of snagging, etc., throughout the rotation.

After all checks indicate satisfactory operation, <u>make sure that the set screws are tight</u>.

b. Coordinate Transformation Circuit

The Sine-Cosine resolvers which are part of the transformation circuit are driven through a timing belt by the Theta drive motor. The alignment of these rosolvers must be done <u>after</u> the Theta angle calibration has been performed as in Section III.B.1.a., and may be performed either while IDCADS is mounted on the telescope or in the laboratory with the adaptor plate and ring gear mounted on the test stand. In either case, the console must be connected to the adaptor plate and ring gear via connector P-4.

1. With <u>Console Power</u> OFF, disconnect the leads going to the telescope from Patch Panel terminals #138 and #140 (in the right rear of the console). From a portable power supply or from the console, supply these two leads with +5 volts.

2. Turn <u>Console Power</u> ON. Press <u>Telescope Guidance</u> control (on Guidance Panel of console) to ON.

3. With a portable d-c meter or oscilloscope, measure the voltage at the output of the DEC coaxial cable coming from the Coordinate Transformation circuit. (The coax should not be connected to the telescope.)

4. Using the <u>Theta Drive</u> control on the console, rotate the Theta Angle through the range from 000° to 360°. Record the angular position of the maximum, zero, and minimum points and the absolute magnitude of the maximum and minimum points.

<u>Criteria</u>: The output of the DEC guidance signal shall appear similar to the curve of Figure 31. The maximum, zero, and minimum points shall occur within ±10° of the points indicated on the curve, and the absolute magnitude of the maximum and minimum points shall be 7.0 ± 1.0 volts.

5. If these criteria are not met, loosen the set screw holding the drive gear from the ring drive motor to the Sine-Cosine resolvers and rotate the resolvers until the criteria are met. Retighten the set screws.

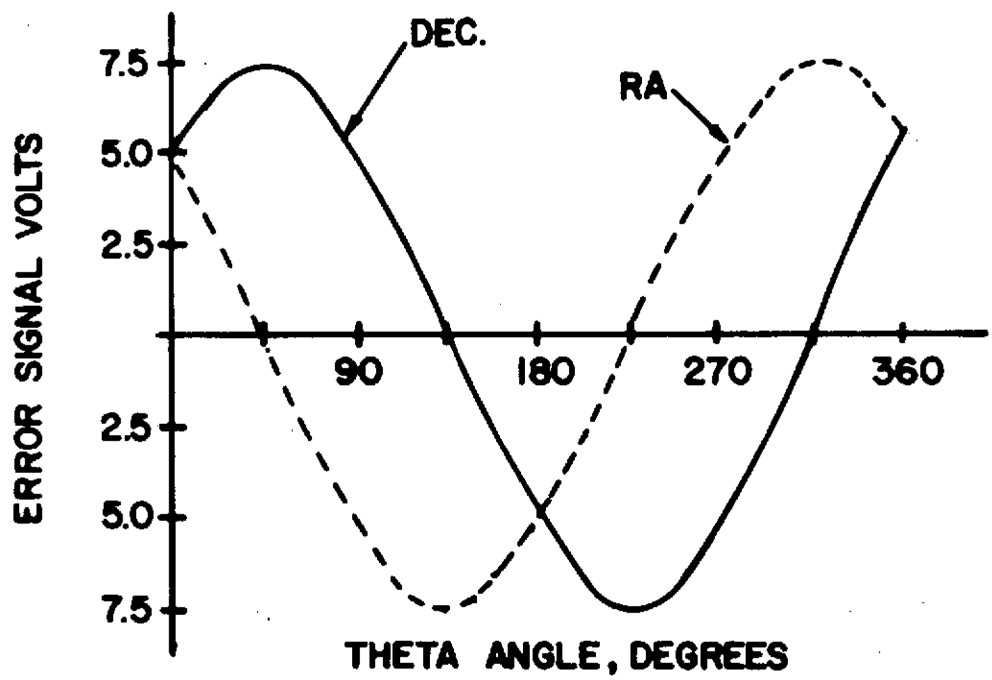


FIGURE 31 : TRANSFORMED GUIDANCE ERROR SIGNAL

6. Push the Telescope Guide control to OFF. The guidance signal must not exceed five millivolts.

7. Repeat steps 1 through 6 for the RA guidance signal coax. NOTE: If the RA signal is out of limits for the curve of Figure 31 (or even close to out of limits), loosen the set screws and juggle the position of the resolvers so that the DEC and RA guidance signals are roughly equally far from "ideal". Both signals must then fall within the criteria of step 4.

8. Turn Console Power OFF, and refasten the leads to terminals #138 and #140.

2. R_1 and R_2 Centering and Distance Traveled

The calibration of these quantities may be done with IDCADS on the telescope, but because of the amount of time involved it is recommended that the calibration be done in the laboratory. The complete instrumentation unit should be mounted on the test stand and all cables connected to the console. Power should be ON for at least one hour to insure complete warm-up. The viewing eyepiece should be mounted in place of the photographic camera.

a. Adjusting the Simulated Star

Mount the simulated star in the base of the test stand so that it is as near the center of the ring gear as is possible to judge by observation. (Have the micrometer travel adjustments set at the center position.) Using the R_1 and R_2 drive controls, move Modules I and II away from the center of the ring gear so that there is clear access to the center. Place a piece of ground glass in a horizontal position 9.50 inches above the bottom surface of the adaptor plate (the surface which mounts to the telescope). Adjust the focus of the simulated star until the star image is focused on the ground glass. (Use a portable eyepiece to insure that a sharp focus is obtained.) This has now located the simulated star at the normal focal plane and near the center of the IDCADS instrumentation package. Remove the ground glass plate.

b. Distance Travelled

By means of C-clamps or other suitable clamps, attach a dial indicator so that the indicator tip contacts a moving part of Module I at right angles. The dial indicator should have a range of travel of at least one inch (greater travel, up to six inches, is desirable). The accuracy and resolution of the distance indicator should be 0.005 inch or better. Put the DVM Select switch on R_1 and note the reading. Use the R_1 drive control to move Module I 1.00 inch (as measured by the dial indicator) and note the new reading on the DVM.

Criteria: The change in voltage readings for 1.00 inch of travel shall be 1.00 ± 0.01 volts.

If the reading is not within specification, use a small screwdriver to rotate the Trimpot which adjusts the regulated voltage supplied to the precision potentiometer used to measure R_1 position, and repeat the measurements. NOTE: Changing the supply voltage changes the reading at all positions of R_1, so that an iterative procedure must be used to bring the readings within limits. Once the criteria has been met, each 1.00 volt change in potentiometer reading indicates 1.00 inch of travel of R_1.

Remove the dial indicator and drive R_1 all the way IN and note that the safety interlock stops the drive motor before Modules I and II collide with each other. Drive R_1 all the way OUT and again note that the interlock stops travel before the module reaches the edge of the adaptor plate. Record the IN and OUT positions in the log book for future reference. Total travel will be approximately six inches.

Repeat the above procedure to calibrate distance travelled for R_2.

c. Centering

Place the Mode Select switch to PHOTO. Operate the R_2 drive control on the console until Module II is in the center. Observe through the eyepiece (which is mounted in place of the camera); the star should be visible in the field of view. By operating the R_2 drive and/or the position micrometers on the simulated star, position the star so that it is in the center of the eyepiece (as determined by the cross hairs).

Operate the Theta Drive control to slowly rotate the ring gear while observing the position of the star; if the star is centered, its apparent position will not change. If it is not centered, its apparent position will move in a circular path. By a process of iteration in which the position of the simulated star and the position of R_2 are both changed, adjust the position of the star until its position does not vary by more than 0.01 inch (approximately two spot diameters) as Theta is rotated. Set the DVM Select to R_2.

In the log book, record the position of R_2 as indicated by the digital voltmeter; this is the center position of R_2.

In order to find the center of R_1, use the R_1 and R_2 drive controls to move R_2 away from the center of the ring gear and to move R_1

into the center. Operate the console View/Guide switch to VIEW, the Master Select to ID-2, Experiment Select to AREA SCAN, Master Timing to VIEW, and set the Scan Parameter switches so as to obtain a one-inch square scan at a rapid scan rate with no scan offset so that the entire cathode of the ID tube is scanned. Press the INITATE button. Adjust the oscilloscope controls so that the scan may be viewed on the oscilloscope screen; the star should appear as a bright spot somewhere in the scan. Drive R_1 until the star is at the center of the scan. (Increase the scale of the oscilloscope presentation with the Scan Parameter switches, etc., to provide greater sensitivity.) Set DVM Select to R_1.

In the log book, record the position of R_1 as indicated on the DVM; this is the center position of R_1.

3. Focus and Alignment for ID Tubes 1 and 2 (Module I)

a. Test Setup

The test setup for this Section is the same as for R_1 Centering (Section III.B.2.c.). The instrumentation package is mounted on the test stand with the system connected and powered and the simulated star mounted and centered in the base of the test stand. Module I should be positioned in the center of the field of view.

b. ID-2 (View)

The focus and alignment of ID-2 may be important and should, therefore, be performed with care. When ID-2 is being used in its primary function, as a TV-type viewer; in order to locate a suitable guide star, focus and alignment are not as critical; however, ID-2 may also be used in a data gathering mode, in which case these parameters are important.

1. Focus — Mechanical and Electrical

With the View/Guide switch in the VIEW position and the Scan Controls set as in III.B.2.c. so as to obtain a one-inch square scan with ID-2, adjust the oscilloscope controls so that the star is visible in the presentation on the oscilloscope. Loosen the clamp bolts on the ID-2 housing and carefully move the housing a short distance in or out (parallel to its axis) while observing the star image; leave the housing at the position which gives the sharpest image (brightest image with the smallest diameter). Adjust the Electrical Focus control on the rear of the console to obtain the sharpest image. This completes the preliminary mechanical and electrical focus adjustments. Before making the final adjustments, procede to III.B.3.b.2. and align ID-2.

After the tube is aligned, return the star image to the center of the viewing screen. Alternately adjust the ID-2 Centering and the Area Scan Dimension controls until the star is bisected with a single horizontal sweep and the X-sweep is three to five star diameters long. Press the Modulation switch to Y-MODULATION and adjust the oscilloscope controls so that the X-sweep is visible on the screen; the star signal will now appear as a rounded pulse in the Y direction. Adjust Y-Centering in small increments until the pulse has maximum height. (This assures that the sweep is passing through the center of the star image.) Note the width of the pulse at the half-power points; carefully adjust the mechanical position of the ID-2 housing in its linear direction until the height of the pulse is a maximum and the width is a minimum. Adjust the Electrical Focus to optimize the same parameters. (NOTE: Changes in the electrical focus voltage may change the deflection sensitivity of the ID tube slightly, so that the apparent position of the star shifts a small amount. Make small adjustements in the Y-Centering to insure that the image is still bisected by the sweep.) Repeat the mechanical and electrical focus adjustments several times to make sure that any interaction between the two adjustments has been compensated for and that optimum focusing has been achieved. Lock the clamp bolts on the ID-2 housing.

Record in the log book both the angular and linear positions of the housing as indicated on the scales attached to the housing. This permits rapid relocation of the housing to its approximately correct position if it is shifted for any reason. Also, record the Focus Current.

2. Alignment.

With the system operating as in the first paragraph of III.B.3.b.1., operate the Scan Parameter controls so that a scan of the simulated star is obtained with the star image near the center of the scan. Use the Theta Drive to rotate the ring gear so that the X-axis of the X-Y table holding the simulated star is in alignment with the guide rails holding Modules I and II. Note the readings of the micrometer drives on the X-Y table. Turn the X-axis micrometer so that the simulated star moves in the same direction as the rails and in the direction of Module I. The star image as viewed on the oscilloscope should move to the right of the screen. If it does not, rotate the ID-2 housing in such a direction so as to make the travel correct. NOTE: Expand the scale on the oscilloscope sufficiently so that the star position may be tracked to within a single spot position.

As a further check, return the X-axis to its original position and move the Y-axis micrometer so as to move the simulated star towards ID-1; the star image should move upwards along the vertical axis. If the star image moves in any other direction, such as downward, the ID tube deflection coils are improperly wired. Return the simulated star to its central position.

Because of the difficulty in accurately aligning the X-Y axes of the simulated star with the axes of the instrumentation unit, it may be desirable to check the alignment while the unit is mounted on the telescope. Set the Theta angle to 270.0 degrees. acquire a star in the field of view and obtain a "picture" of the star on the oscilloscope while using ID-2 in an Area Scan View mode. Drive the telescope a small distance of increasing right ascension; the star image should move to the right of the presentation staying on the same horizontal sweep line. If it does not, rotate the ID-2 housing until this condition is satisfied. Likewise, driving the telescope so as to increase the declination angle should move the star image upwards in the vertical axis.

Return to Section III.B.3.b.1. to complete the focusing procedure.

c. ID-1 (Guidance)

Focus and alignment of ID-1 is not as critical as for ID-2. The guidance circuit will function normally even if the star image is somewhat out of focus, and, since the guidance system is a closed-loop nulling system, some misalignment in the X and Y axes will not cause serious errors.

1. Focus — Mechanical and Electrical

In order to focus and align ID-1, operate the View/Guide switch to GUIDE. With a portable oscilloscope, monitor the output of the preamplifier associated with ID-1. Operate the controls on the Guidance Panel so that Lock-On is obtained on the simulated star; at this time the output of ID-1 will have the characteristics of a star signal — increased output with considerable "noise" on top of the signal. Loosen the bolts holding the ID-1 housing in its brackets and move the tube back and forth in its cradle until a maximum signal is obtained. NOTE: If at any time the signal saturates, as indicated by a large, flat-topped signal with no noise on the flat portion, either reduce the brightness of the simulated star or reduce the high voltage supply to ID-1 until the signal is no longer saturated.

Adjust ID-1 Electrical Focus on the back of the console for maximum signal. Repeat both the mechanical and electrical focus several times to insure best focus.

2. Alignment.

Connect one channel of a dual channel oscilloscope to Terminal #138 of the Patch Panel (X-Guidance signal) and the other channel to #140 (Y-Guidance signal). With lock-on obtained and the system balanced, the two guidance signals should be approximately zero. Using the micrometer adjustments to move the artificial star, move the star in the plus-X direction (in the same direction as the guide rails for R_1 and R_2 and towards Module I; the X-Guidance signal should increase in a positive direction. The Y-Guidance signal should remain zero. If these conditions are not met, rotate ID-1 in its housing until the conditions are met. Then move the star in the plus-Y direction (movement at right angles to the guide rails and away from Module II). The Y-Guidance signal should momentarily increase in a positive direction while the X signal remains zero. (If this condition is not met, the deflection coils on ID-1 are improperly wired.) Tighten the bolts on the ID-1 housing. Record in the log book the angular and linear positions of the housing as indicated on the scales attached to the housing. Also, record the Electrical Focus current.

4. Description of Calibration Unit for Use with Data Gathering Unit (Module II)

Calibration (focus, alignment, scale constant, and cathode response) of ID tubes 3 and 4 is important since these are the chief data gathering detectors for area scan operation. A special calibration unit (see Figure 32) is incorporated into the instrumentation unit to facilitate this calibration and is mounted on Module II. An optical schematic is shown in Figure 33. The principle parts are (a) a one-inch diameter uniform white light source, consisting of a four-inch diameter integrating sphere illuminated with three miniature light bulbs, (b) an Opal diffusing plate, (c) a filter slide, (d) a reticule slide, and (e) a field lens. The filter slide has three positions — clear, blue, and red. The reticule slide also has three positions — clear, a square grid pattern with one-mm spacing for the grid lines (every fifth line accentuated), and an artificial star field containing a variety of different sized stars.

For the method of operation of the calibration unit, refer back to Figure 16. With the Optics Position (Mode Select) switch on CALIBRATE, the

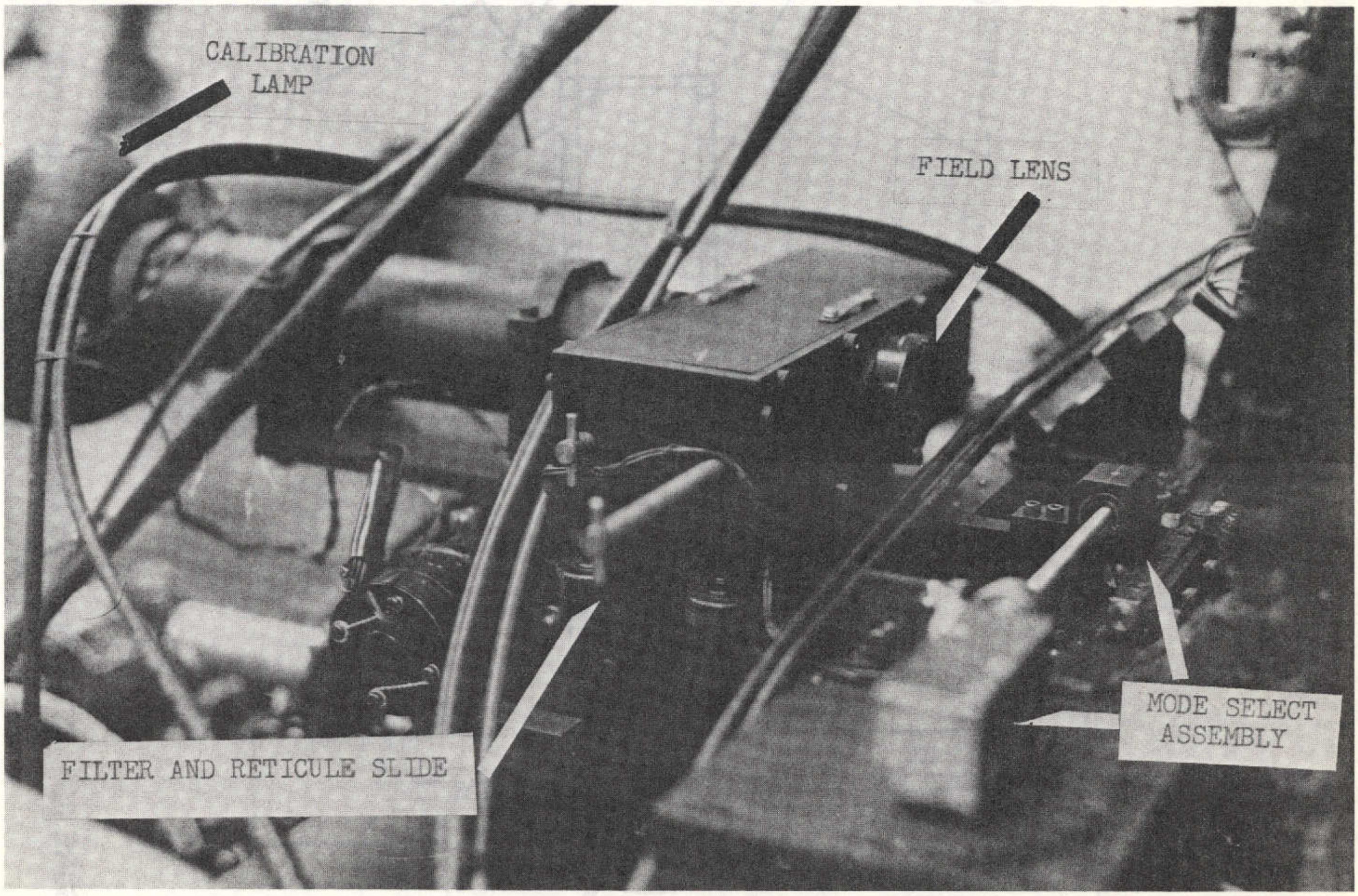


Figure 32: CALIBRATION ASSEMBLY

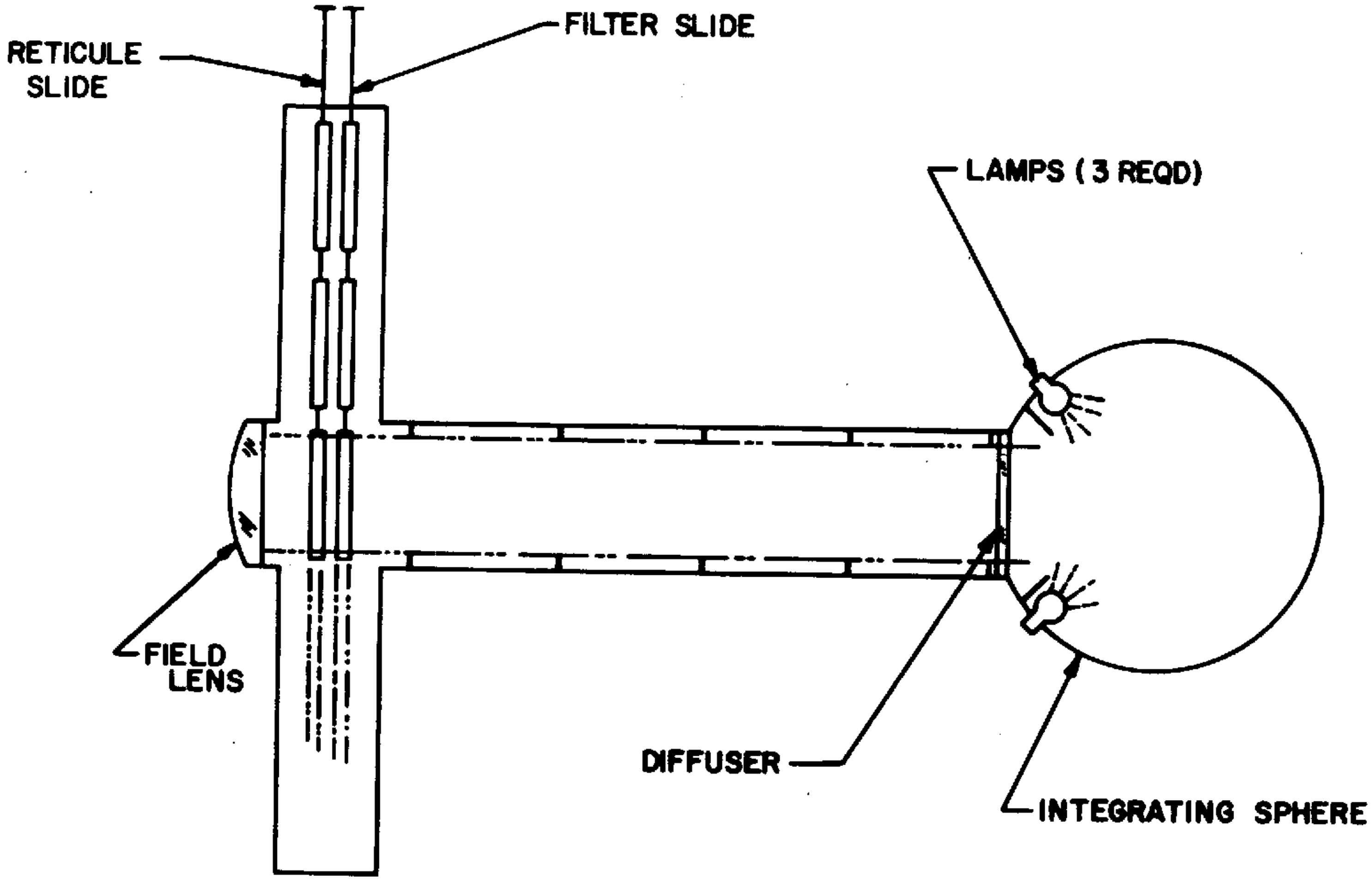


FIGURE 33: OPTICAL SCHEMATIC OF CALIBRATION UNIT

mode select assembly (B) is moved out of the way so that the calibration unit (E) is in line with and has a clear view of the transfer lens (C). The illuminated reticule in the calibration unit is the same distance from the transfer lens as is the focal plane of the telescope, and the field lens in the calibration unit is at the same optical distance and has the same optical qualities as the field lens on the mode select assembly. Thus the reticule from the calibration unit is relayed to the detector selected by the detector select assembly (D) as though it were an image from the focal plane of the telescope.

5. Focus, Alignment, Scale Constant, and Cathode Response of ID Tubes 3 and 4

a. Focus and Alignment

A preliminary focus and alignment should be performed for both ID-3 and ID-4 using the procedure for ID-2 (Section III.B.3.b.), in which the artificial star in the center of the test stand is utilized as a test source. The only change is that the console control switches must be set for ID-3/4 AREA SCAN VIEW instead of ID-2 AREA SCAN VIEW. Use the Master Select switches to select ID-3 as the detector and perform focus and alignment on ID-3; then repeat the procedure for ID-4 with the Master Select set for ID-4. This preliminary focus and alignment insures that the deflection coil connections are correct and that the tubes are approximately aligned.

Now set the Optics Position switch (Mode Select) for CALIBRATION 3/4 so that the calibration unit may be viewed. Place the reticule selection slide so as to have the one-mm grid in position, set the filter select slide to CLEAR, and turn the Calibration Lamp ON. Select ID-3 as the detector, and operate the scan controls until a view of the grid is seen on the oscilloscope. Increase the scale of the presentation until the individual scan lines may be clearly observed. If necessary, rotate the ID-3 housing until the X-sweep lines are aligned with the X-grid lines to within 0.005 inch per inch of deflection. The Y-sweep lines should also be within this tolerance with respect to the Y-grid lines. NOTE: Since the deflection coils of the ID tube may not be perfectly orthogonal, some repositioning of the housing may be required to get both axes within specification.

The focus adjustment should be checked, and readjusted if necessary, following the procedure of Section III.B.3.b.1. except that one of the reticule grid lines should be used as the "target" instead of the simulated star. Tighten the bolts on the ID-3 housing.

Select ID-4 as the detector and repeat the above procedure to align and focus ID-4.

Record the angular and linear positions of the ID-3 and ID-4 housings in the log book, as well as the Electrical Focus values for each tube.

b. Scale Constant

Continue with the same test setup in order to check the scale constants for the X and Y deflection circuits. Select ID-3 as the detector and obtain a view of the one-mm grid reticule on the oscilloscope. Set the Scan Controls so that a single X-sweep is obtained with approximately 100 steps of 0.001 inch step size. Adjust the scale of the oscilloscope presentation so that the individual steps may be observed. Count the number of steps between two of the one-mm grid lines.

Criteria: There should be 39.3 ± 0.5 steps; if this condition is not met, adjust the X-gain in the sweep control chassis of the console.

Set the Scan Controls so that a similar single sweep is obtained in the Y-axis and check the Y-gain setting, adjusting the control until the above criteria is met.

c. Cathode Response

Continue with the same test setup as in the preceeding section, except that the reticule select rod on the calibration unit should be set to the CLEAR position. Select ID-3 as the detector, and adjust the Scan Controls so that a one-inch by one-inch scan is obtained with a 100 x 100 raster (step size 100 points to the inch). Set the oscilloscope controls so that the entire scan is visible on the screen. The round cathode of the ID tube should be clearly visible; adjust the centering controls so that the cathode is centered in the scan. Keep the scan raster centered on the cathode while reducing the scan size to 60 x 60. (This gives 3600 scan points, the maximum that can be conveniently stored in the computer memory core.) Turn out the room lights so that no stray light may reach the ID tube. Observe the signal count on the A-counter for each scan point; set the Point Dwell Time switches so that several hundred counts are obtained for each point.

NOTE: An alternate, and probably preferred procedure, is to set the Point Dwell Time so that only 1/10th to 1/20th as many counts are obtained on each scan point; then set the Master Timing selector to TIME and set the Time Interval switch to a large enough time so that 10 (or 20) complete scans will be obtained. This results in a total count per point which is approximately the same as before, but the effects of any signal drift will be minimized.

Set the Data Record Mode selector to CORE, make sure that the computer is properly set to record an area scan, and perform an AREA SCAN. A calibration scan indicating the relative sensitivity of the central 3600 points of the ID cathode is now stored in the computer; this data may be printed out or stored on magnetic tape for use in data reduction for future runs.

Repeat this procedure for ID-4.

6. Focusing the Photographic Unit

Mount the photographic unit in place of the viewing eyepiece, with a ground glass viewing screen in place of the photographic plate holder. Turn the Optics Position (Mode Select) selector to CAL PHOTO. Turn the Calibration Lamp ON and position the reticule select slide so that the one-mm grid is in place. Darken the room so that the projected grid may be viewed on the ground glass screen. Loosen the clamping bolts holding the photographic unit and slide the unit back and forth until the grid lines are sharply in focus. If necessary, use a magnifying eyepiece to view the grid lines in order to obtain the sharpest focus. Tighten the mounting bolts and remove the ground glass screen.

C. Installation

This section will cover in some detail the installation of IDCADS on the 90-inch telescope. In order to utilize IDCADS with a different telescope, an adaptor plate specifically designed for that telescope is required for mounting the instrumentation unit (see Section I.D.1.) and different cabling between the control console and the telescope would be required; other than this, the installation procedure would be approximately the same as for the 90-inch.

Installation consists of mounting the instrumentation package on the telescope, connecting the necessary cabling from the control console to the telescope and the instrumentation package, and focusing and balancing of the telescope.

1. Hookup to the Telescope

Prior to mounting the IDCADS instrumentation unit to the telescope, perform the following operations: (a) position the telescope so that it is pointing at the zenith; this insures that the Cassegrain mounting ring of the telescope is at its lowest position for easy access and is horizontal;

(b) remove any instrumentation packages which may be mounted to the Cassegrain mounting ring; (c) make sure that the probe from the automatic guider is positioned clear of the field of view. Remove the handle from the shaft used to position the probe; otherwise, there is interference between the handle and the IDCADS adaptor plate and ring gear.

a. Attach Adaptor Plate and Ring Gear

The adaptor plate and ring gear assembly is transported on a wooden holding fixture which also serves as a test stand in the laboratory (see Figure 3). For ease in testing in the laboratory, the instrumentation package is mounted "up-side-down" (reversed from the telescope mounting position) on the test stand. This results in the adaptor plate and ring gear being reversed from the desired position on the telescope, so that the assembly must be turned over before mounting. The most expedient way of handling this assembly is the brute force method — use a minimum of three reasonably strong people for the installation. After removing the bolts which hold the adaptor plate to the holding fixture, pick up the assembly and turn it over so that the drive motor and Theta encoder extend upward. Carry the assembly to the telescope and hold it well below the Cassegrain mounting ring. Rotate the assembly in the horizontal plane until the drive motor and Theta encoder are located next to the guider shaft from which the handle was removed. Carefully lift the assembly until it contacts the Cassegrain mounting ring, making sure that no part of the assembly "bumps" any part of the telescope. Position the assembly so that the ten clearance holes in the adaptor plate line up with the ten mounting holes in the Cassegrain ring. (Note that there is only one position in which all of the holes will match, since the holes are not symmetrical, but are arranged in four groups of two holes and two singles.) Have two people hold the assembly in position while the third engages some of the 3/8-inch cap head mounting bolts. <u>IMPORTANT</u>: A spacer bushing and washer (as shown in the expanded view of Figure 34) must be used with each mounting bolt; otherwise, the head of the mounting bolt will slip through the clearance hole in the adaptor plate, permitting the assembly to fall.

After several of the mounting bolts have been engaged around the periphery of the adaptor plate and tightened several turns, the people holding the assembly in place may carefully relax their lifting force until the entire weight of the assembly is held by the mounting bolts. Once it is evident that the bolts are holding, each person may add other bolts until all ten are installed. Using a suitable Allen wrench, securely tighten all

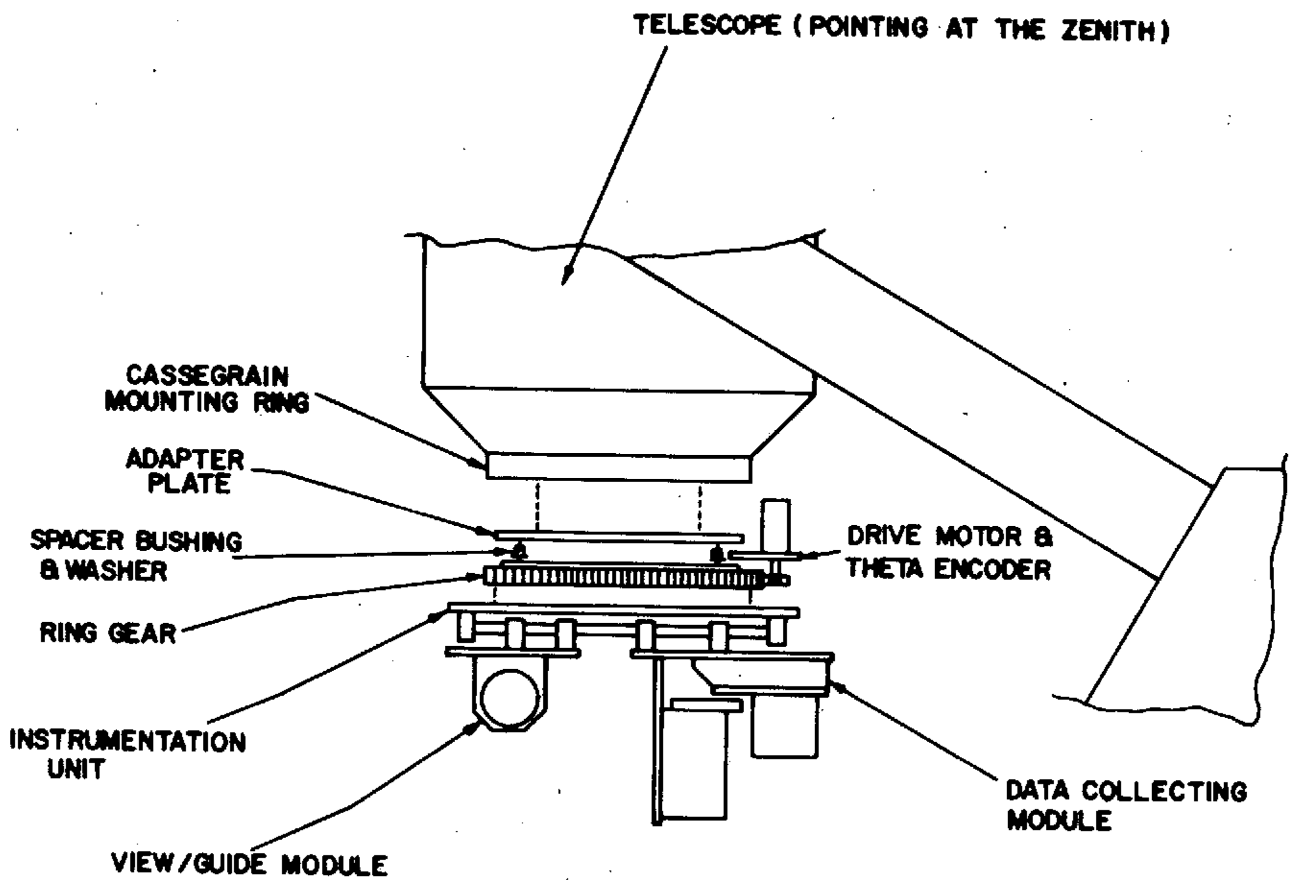


FIGURE 34 EXPANDED VIEW OF MOUNTING PROCEDURE

of the bolts.

Check to see if the arrow which has been etched on the ring gear with an electric pencil is pointing to geographic East; if it is not, hook up the cables from the control console to the telescope as described in Section III.B.1.c. (except that the plugs to the instrumentation unit will not be connected) and use the Theta Drive controls on the console to rotate the ring gear until the Theta Readout on the console indicates 270°. (This is telescope West or geographic East.) At this time the etched arrow should point to geographic East; if it does not, the ring gear must be realigned following the procedure of Section III.A.1.

b. Attaching Main Instrumentation Unit

The instrumentation unit is transported on a dolly constructed from lengths of 1 1/2-inch pipe fitted together so as to form a protective frame around the unit. The dolly has four castors so that it may be rolled across the floor. CAUTION: When rolling the dolly with the instrumentation unit attached, take care that no protruding objects are permitted to strike and damage the instrumentation unit; the protective metal framework does not give complete protection. The instrumentation unit is mounted "right-side-up" on the dolly, so that no reversal is required for installation.

After the adaptor plate and ring gear have been mounted on the telescope, roll the dolly under the telescope and position the dolly so that the guide rails carrying Modules I and II run in the East-West direction and Module I is located at the geographic East end. Position a battery-powered fork lift so that the lifting forks are under the bottom rails of the dolly. Again, using three people (two to steady the unit and one to operate the fork lift), use battery power to operate the lift and slowly raise the dolly and instrumentation unit until the top of the instrumentation unit is three to six inches from the bottom of the ring gear. During the lifting process, the two assistants should steady the unit on the fork lift and carefully observe that there is no mechanical interference during the lifting process; because of the large masses and forces involved, damage to either the instrumentation unit or the telescope can occur with little warning if utmost care is not exercised.

Use the hand pump on the fork lift to slowly raise the unit until it is about 1/4 inch from contacting the ring gear. Insert some of the 3/8-inch mounting bolts through the base plate of the instrumentation unit into the mating holes in the ring gear (some slight "jiggling" of the unit may be necessary in order to get the holes properly aligned so that the bolts will engage.) When eight or more of the 18 bolts are securely engaged somewhat uniformly around the periphery of the unit, tighten the bolts enough with an Allen wrench so that the instrumentation unit and dolly are no longer supported by the fork lift. Loosen and remove the eight 1/4-inch bolts holding the dolly to the instrumentation unit. The fork lift and the dolly may then be lowered and removed, giving more room to install the remainder of the mounting bolts. Install the remainder of the mounting bolts and securely tighten all of the bolts.

c. Cable Hookup

The interconnections between the IDCADS control console and the telescope and/or instrumentation unit were described in Section II.C. and shown in Figure 28. Four cables, C-1, 2, 3, and 4 connect from the console to the junction box mounted near the telescope pedestal, and C-5 connects from the console to the telescope paddle input on the Coude station. These five cables are normally left stowed in the cable troughs in the pedestal room. The ends P-15, 16, 17, 18, and 19 are passed through the access hole in the floor of the instrumentation room and attached to the console. The other ends, P-10, 11, 12, 13, and the paddle, are connected to the junction box and to the Coude station.

The harness, H-1, connects from the junction box on the telescope to the instrumentation unit and the ring gear. Plugs P-6, 7, and 8 connect to the junction box and contain a total of 135 signal wires; the terminations of these wires are P-01, 1, and 2, on the instrumentation unit and P-4 on the ring gear. Power is carried on three heavy wires from P-9 on the Cassegrain mounting ring to P-3 of the instrumentation unit. Connect high voltage and signal coaxial cables as required from the experiment unit directly to the control console; leave plenty of slack in the cables so that the telescope can move without excessive drag on the cables.

After all cables are connected, energize the console and check all electro-mechanical operations of the system by operating the proper control switch on the console and visually observing the action at the IDCADS unit on the telescope. Operations which should be checked include the Theta drive and readout, the R_1 and R_2 drives and readouts, the operation of the detector select and mode select assemblies and the status indication on the console, the opening and closing of the shutters for the ID tubes, and the operation of the filter select wheels. If any function fails to operate, the trouble can usually be traced to a loose connector or to mechanical interference of some part or cable which is out of place.

2. Balancing the Telescope

After the instrumentation unit is mounted and all cables are connected, the balance of the telescope must be adjusted. Have the telescope operator activate the telescope, remove the preload, and drive it slowly so as to first increase and then decrease the declination angle while observing the drive amplifier voltage. Adjust the declination balance weights until the drive voltage is the same (±10%) for the two directions. Repeat the procedure by driving the telescope in ascension angle and adjusting the ascension balance weights. Record the position of the balance weights in the telescope log book so that for future operations with IDCADS the balance of the telescope may be set without repeating the balancing operation.

3. Focusing the Telescope

Focusing must be performed at night when stars may be observed. Have the telescope and IDCADS powered and working and the dome open. Replace the IDCADS photographic unit with the viewing eyepiece. Have the telescope operator drive the telescope to the coordinates of a suitable star located near the zenith, and adjust the telescope focus control to obtain focus approximately eight inches outside the normal Cassegrain focus. Use the R_1 and R_2 Drive controls to drive Module I to the edge of the field of view and Module II to the center of the field of view. (The center position of R_2 was determined during calibration in Section III.B.2.c. and recorded in the log book; set the DVM Select switch to R_2 and position R_2 until the reading on the digital voltmeter indicates the center position.) Operate the Mode Select switch to PHOTO. Look through the eyepiece. The selected star should be visible; if it is not, make minor corrections in the telescope position until the star appears. Adjust the telescope focus until the star image is in sharp focus. This is approximately the optimum focus.

Use the procedure of Section III.B.3. (except that now a real star rather than a simulated star is being used) for the final focusing adjustment. (NOTE: Do not loosen the clamps and adjust the mechanical position of any of the ID tubes during this adjustment.) Operate the console controls to ID-3 AREA SCAN, and adjust the Area Scan controls so that the star is visible in the area scan; further adjust the Area Scan controls so that the image is bisected with a single horizontal sweep and the X-sweep is three to five star diameters long. Press the Modulation switch to Y-MODULATION and adjust the oscilloscope controls so that the X-sweep is visible on the screen. The star signal will now appear as a rounded pulse in the Y-direction. Adjust Y-Centering in small increments until the pulse has maximum height. Noting the width of the pusle at the half-power points, carefully adjust the telescope focus until the height of the pulse is a maximum and the width is a minimum. This is the optimum focus point.

Record the telescope focus position in the telescope log book for future use.

4. Removing IDCADS from the Telescope

When the observing schedule has been completed, the IDCADS system is removed from the telescope. Before starting removal, three preparatory steps should be performed: (1) have the telescope operator position the telescope so that it is pointing at the zenith, (2) use the console Theta Drive to position the ring gear so that the Theta Readout indicates 270° (geographic East), and (3) make sure that all IDCADS' shutters are closed. The removal procedure is now the inverse of the installation procedure: disconnect the cables, remove the instrumentation unit, remove the adaptor plate and ring gear, and restore the telescope to its original condition.

After shutting down IDCADS and telescope power, disconnect the IDCADS' cables that were connected in Section III.B.1.c. These include signal and high voltage coaxial cables between the console and the instrumentation unit, the cable harness H-1 between the instrumentation unit and the telescope junction box, and the five cables (C-1, 2, 3, 4, and 5) from the console to the telescope pedestal room. The coaxial cables should be rolled up and taped for storage and the five cables from the console to the pedestal should be dropped through the access feedthrough in the floor of the instrumentation room and stowed in the cable troughs.

To remove the instrumentation unit, loosen all 18 of the 3/8-inch mounting bolts holding the instrumentaiton unit to the ring gear. Lift the metal carrying and test dolly and fasten it to the adaptor ring with the eight 1/4-inch bolts. Position the battery powered fork lift beneath the instrumentation unit and carefully raise the fork arms until they just contact the lower rails of the dolly. (IMPORTANT: Use the manual pump for the last three to six inches of travel of the fork lift to insure that there is no over travel.) Remove the bolts holding the instrumentation unit to the ring gear. Have at least one and preferably two people steady the instrumentation unit while the fork lift operator carefully lowers the dolly and unit to the floor. Roll the dolly and the unit to one side and cover the unit with the plastic dust cover.

Position the wooden carrying dolly for the adaptor plate and ring gear under the telescope. Remove five or six of the 3/8-inch mounting bolts, washers, and spacing bushings which hold the adaptor plate and ring gear to the Cassegrain flange, making sure that the remaining bolts are evenly spaced around the periphery of the unit. Loosen the remaining bolts several turns. Have two people lift up on the adaptor plate and ring gear while a third removes the remaining bolts. The three people can then lower the assembly to a more comfortable height and turn the unit over (so that the Theta drive motor and encoder are downward). Place the unit on the dolly. Locate the spacing bushings and washers over the mounting holes and fasten the unit to the dolly with lag bolts. Place the 3/8-inch mounting bolts in the recess in the center of the dolly for storage and cover the unit with the plastic dust cover.

Return the telescope to its original condition by reattaching the handle for the guider probe.

5. Storage

The protective measures required for storage of IDCADS depends upon the place of storage. If the system is stored in the laboratory where temperature and humidity conditions are moderate, the instrumentation unit and adaptor plate and ring gear may be left on their carrying dollies and kept covered with the plastic dust covers. If they are to be stored for any appreciable length of time in the telescope dome or other location which has wide temperature and humidity extremes, it is advisable to store the units in gasket-sealed containers.

In any case, the ring gear and mating pinion are fabricated from an alloy steel which is highly susceptible to rust, so these parts should be kept coated with a thin layer of heavy oil or light grease. Other steel parts, such as the precision lead screws, should periodically be wiped with an oily cloth.

IV. MAINTENANCE, REPAIR, AND TROUBLE SHOOTING

A. Electro-Mechanical Parts

Maintenance of the electro-mechanical portions of IDCADS consists mainly of keeping the moving parts free of foreign particles, binding parts, and wires and cables which have twisted into such a position as to interfere with the motion of some of the mechanical subassemblies. Set screws in couplings, etc., may work loose, allowing drive shafts to slip.

There is little chance of component failure in this portion of the system; drive motors are conservatively rated and are operated with very low duty cycles. The electro-mechanical failure which would be most likely to lead to serious complications would be the failure of one of the limit switches so that one of the drive motors could drive a unit beyond its mechanical stop, causing either mechanical damage or burn out of the motor. Such a malfunction is readily apparent if a close watch is kept on the system status indicators, and will normally be noted in time to prevent serious damage or burnout.

In the case of a failure of any of the mechanical or electro-mechanical parts, the replacement of these parts is usually a simple matter. However, it will often be necessary to recalibrate all or part of the system, using the procedures described in Section III, after the replacement of damaged mechanical parts; this may be a tedious and time consuming process, requiring more time than the actual repair.

B. Electronic Parts.

There are only a few electronic parts in the instrumentation unit. The circuits, which are most likely to give trouble, are the amplifiers for the ID tubes; the theory and repair of these units are described in Volume II. Other electronic units include the signal processing unit and the X-Y coordinate transformation circuit. In case of malfunction of these units, trouble shooting should be performed using a multimeter and/or an oscilloscope and the functional schematics in Section II and the more detailed schematics in the Appendix.

C. Image Dissector Tubes

Although image dissector tubes are precision scientific instruments, they are inherently rugged and long lived. There is no heater to burn out, and they are not easily damaged by temporary overloads, although there is some deterioration of cathode response over long periods of time. Prudence indicates that the ID tubes should not be exposed to bright light when powered, and <u>never</u> to direct sunlight.

The chief problem encountered with the ID tubes was a tendency for the tubes and/or high voltage resistor strings to break down under high voltage. Incipient breakdown is heralded by an increase in background noise, with bursts of noise occuring at irregular intervals. If this is noted, reduce the high voltage to the tube immediately. Operation should always be conducted with as low a voltage as will give sufficient signal gain (usually 1700 to

1800 volts), and should never exceed 2000 volts.

D. Cleaning the Optics

It is important that the optical elements be kept free from dirt and contamination; these elements include the transfer lens, the elements of the mode select and the detector select systems, and the filters, as well as the viewing eyepiece and the optical elements of the calibration unit. The most effective treatment is preventative maintenance, keeping the elements covered when not in use so that they will be exposed to a minimum of dirt and contamination.

If some of the optical elements do become dirty, a cleansing operation is required. The first step is to gently blow the affected surfaces with a stream of air from either a hand bellows or from an air hose containing clean, filtered air. If this is not successful, the surfaces should be brushed with a clean camel's hair brush. If the surfaces are still contaminated, they may be cleaned by <u>gently</u> rubbing them with a piece of lens tissue containing a small amount of chemically pure alcohol.

E. Calibration Lamps

The calibration unit for calibrating ID tubes 2 and 3 (see Section III.B.4.) and the calibration unit for the photographic unit (see Section II.A.3.c.) contain a number of small incandescent bulbs in an integrating sphere intended to provide a uniform light source. These bulbs should be checked periodically to insure that none of them have burned out; this would result in a nonuniform source.

F. Multiplex Circuits

Malfunction of the multiplex circuits can result in system operation which is wierd and confusing, since improper signal lines may be connected. By referring to the schematics and wire running lists in the Appendix, it may be determined what multiplex relays are supposed to be activated for each of the operating modes. A logic decoding network directs the activation signals to the proper relays.

G. Cleaning and Lubrication

It is important that the electro-mechanical assemblies be kept clean and free from contamination and foreign matter. The units should be covered with dust covers whenever possible. Periodically all moving parts such as the ring gear, lead screws, and precision guide rails should be examined for dirt and cleaned if necessary. None of these parts are physically delicate, so cleaning with brushes and oil or solvent soaked cloths is proper. If an air hose is used to blow off dust and dirt, care should be taken to insure that dirt is not blown into the ball bearings or bushings.

There are no moving parts which have oil cups which require periodic lubrication; however, all moving gears and guide rails should have a thin film of oil. In particular, the ring gear and mating pinion must have a thin film of oil or grease to prevent rusting.

APPENDIX

(A) WIRE LISTS (PATCH PANEL)

(B)* CABLE WIRE LISTS

(C) SUB-SYSTEMS SCHEMATICS

*See Figure 28 on Page 52 for Reference as to Location of Connectors.

WIRE LIST — MULTIPLEX RELAY

Relay Number	N.O. Position From	N.O. Position To	Wiper Position From	Wiper Position To	Relay Number	N.O. Position From	N.O. Position To	Wiper Position From	Wiper Position To
K1-2-1	J2-A	K2-2-1		P4-e	K2-2-1	K1-2-1	K3-2-1	B3-BLK	K3$\overset{W}{-}$2-1
K1-2-2	J2-B	K2-2-2		P4-f	K2-2-2	K1-2-2	K3-2-2	B4-BLK	K3$\overset{W}{-}$2-2
K1-2-3	J2-C	K2-2-3		P4-h	K2-2-3	K1-2-3	K3-2-3	B4-RED	K3$\overset{W}{-}$2-3
K1-2-4	J2-D	K2-2-4		P4-g	K2-2-4	K1-2-4	K3-2-4	B3-RED	K3$\overset{W}{-}$2-4
K1-2-5	J2-E	K2-2-5		P4-s	K2-2-5	K1-2-5	K3-2-5	TB5-4	K3$\overset{W}{-}$2-5
K1-2-6	J2-F	K2-2-6		P4-j	K2-2-6	K1-2-6	K3-2-6	TB5-5	K3$\overset{W}{-}$2-6
K1-2-7	J2-G	K2-2-7		P4-k	K2-2-7	K1-2-7	K3-2-7	TB6-4	K3$\overset{W}{-}$2-7
K1-2-8	J2-H	K2-2-8		P4-m	K2-2-8	K1-2-8	K3-2-8	TB6-5	K3$\overset{W}{-}$2-8
K1-2-9	J2-J	K2-2-9		TB1-1	K2-2-9	K1-2-9	K3-2-9	CALIB LAMPS	K3$\overset{W}{-}$1-2
K1-2-10	J2-K	K2-2-10		TB1-2	K2-2-10	K1-2-10	K3-2-10		TB7-5
K1-2-11	J2-L	K2-2-11		TB1-3	K2-2-11	K1-2-11	K3-2-11		TB7-6
K1-2-12	J2-M	K2-2-12		TB1-4	K2-2-12	K1-2-12	K3-2-12		TB7-1
K1-1-1	J2-N	K2-1-1		TB2-1	K2-1-1	K1-1-1	K3-1-1		TB7-7
K1-1-2	J2-P	K2-1-2		TB2-2	K2-1-2	K1-1-2	K3-1-2		TB7-8
K1-1-3	J2-R	K2-1-3		TB2-3	K2-1-3	K1-1-3	K3-1-3		TB7-11
K1-1-4	J2-S	K2-1-4		TB2-4	K2-1-4	K1-1-4	K3-1-4		TB7-13
K1-1-5	J2-T	K2-1-5		S2-C	K2-1-5	K1-1-5	K4-2-5		TB7-14
K1-1-6	J2-U	K2-1-6		S1-C	K2-1-6	K1-1-6	K4-2-6		TB7-15
K1-1-7	J2-V	K2-1-7		S1-NC	K2-1-7	K1-1-7	K4-2-7		TB7-16
K1-1-8	J2-W	K2-1-8		S5-C	K2-1-8	K1-1-8	K4-2-8		TB7-2
K1-1-9	J2-X	K4-2-9		S4-NC	K3-2-1	K2-2-1	K4-3-1	K2$\overset{W}{-}$2-1	K4$\overset{W}{-}$1-1
K1-1-10	J2-r	K4-2-10		S4-C	K3-2-2	K2-2-2	K4-3-2	K2$\overset{W}{-}$2-2	K4$\overset{W}{-}$2-10
K1-1-11	J2-d			SPARE	K3-2-3	K2-2-3	K4-3-3	K2$\overset{W}{-}$2-3	K4$\overset{W}{-}$2-11

MULTIPLEX RELAY — con't.

Relay Number	N.O. Position From	N.O. Position To	Wiper Position From	Wiper Position To
K3-2-4	K2-2-4	K4-3-4	K2$\overset{W}{-}$2-4	K4$\overset{W}{-}$2-12
K3-2-5	K2-2-5	K4-3-5		K2$\overset{W}{-}$2-5
K3-2-6	K2-2-6	K4-3-6		K2$\overset{W}{-}$2-6
K3-2-7	K2-2-7	K4-3-7		K2$\overset{W}{-}$2-7
K3-2-8	K2-2-8	K4-3-8		K2$\overset{W}{-}$2-8
K3-2-9	K2-2-9	K4-3-9	TB8-1	K4$\overset{W}{-}$3-8
K3-2-10	K2-2-10	K4-3-10	TB9-1	K4$\overset{W}{-}$3-6
K3-2-11	K2-2-11	K4-3-11	TB9-2	K4$\overset{W}{-}$3-7
K3-2-12	K2-2-12	K4-3-12	TB9-5	K4$\overset{W}{-}$3-5
K3-1-1	K2-1-1	K4-2-1	TB8-2	K4$\overset{W}{-}$3-1
K3-1-2	K2-1-2	K4-2-2	K2$\overset{W}{-}$2-9	K4$\overset{W}{-}$3-7
K3-1-3	K2-1-3	K4-2-3	TB9-7	K4$\overset{W}{-}$3-4
K3-1-4	K2-1-4	K4-2-4	TB9-8	K4$\overset{W}{-}$3-3
K4-3-1	K3-2-1	K5-3-1		K3$\overset{W}{-}$1-1
K4-3-2	K3-2-2	K5-3-2		K3$\overset{W}{-}$1-2
K4-3-3	K3-2-3	K5-3-3		K3$\overset{W}{-}$1-4
K4-3-4	K3-2-4	K5-3-4		K3$\overset{W}{-}$1-3
K4-3-5	K3-2-5	K5-3-5		K3$\overset{W}{-}$2-12
K4-3-6	K3-2-6	K5-3-6		K3$\overset{W}{-}$2-10
K4-3-7	K3-2-7	K5-3-7		K3$\overset{W}{-}$2-11
K4-3-8	K3-2-8	K5-3-8		K3-2-9
K4-3-9	K3-2-9	K5-3-9		TB8-3

Relay Number	N.O. Position From	N.O. Position To	Wiper Position From	Wiper Position To
K4-3-10	K3-2-10	K5-3-10		TB8-4
K4-3-11	K3-2-11	K5-3-11		TB8-5
K4-3-12	K3-2-12	K5-3-12		TB8-6
K4-2-1	K3-1-1	K5-2-1		TB10-1
K4-2-2	K3-1-2	K5-2-2		TB10-2
K4-2-3	K3-1-3	K5-2-3		TB10-5
K4-2-4	K3-1-4	K5-2-4		TB8-7
K4-2-5	K2-1-5	K5-2-5		TB10-7
K4-2-7	K2-1-7	K5-2-7		TB8-8
K4-2-8	K2-1-8	K5-2-8		TB8-9
K4-2-9	K1-1-9	K5-2-9		TB8-10
K4-2-10	K1-1-10	K5-2-10	K3$\overset{W}{-}$2-2	K5-3-8
K4-2-11	J2-Z	K5-2-11	K3$\overset{W}{-}$2-3	K5-3-9
K4-2-12	J2-a	K5-2-12	K3$\overset{W}{-}$2-4	K5$\overset{W}{-}$3-7
K4-1-1	J2-b	K5-1-1	K3$\overset{W}{-}$2-1	K5$\overset{W}{-}$3-6
K5-3-1	K4-3-1			TB8-11
K5-3-2	K4-3-2			TB3-4
K5-3-3	K4-3-3			TB3-5
K5-3-4	K4-3-4			TB4-4
K5-3-5	K4-3-5			TB4-5
K5-3-6	K4-3-6			K4$\overset{W}{-}$1-1
K5-3-7	K4-3-7			K4$\overset{W}{-}$2-12

MULTIPLEX RELAY — con't.

Relay Number	N.O. Position From	N.O. Position To	Wiper Position From	Wiper Position To	Relay Number	N.O. Position From	N.O. Position To	Wiper Position From	Wiper Position To
K5-3-8	K4-3-8			K4^{W}-2-10					
K5-3-9	K4-3-9			K4^{W}-2-11					
K5-3-10	K4-3-10			TB11-1					
K5-3-11	K4-3-11			TB11-2					
K5-3-12	K4-3-12			TB11-3					
K5-2-1	K4-2-1			TB11-4					
K5-2-2	K4-2-2			TB11-5					
K5-2-3	K4-2-3			TB11-6					
K5-2-4	K4-2-4			TB8-12					
K5-2-5	K4-2-5			TB12-1					
K5-2-6	K4-2-6			TB12-2					
K5-2-7	K4-2-7			TB8-13					
K5-2-8	K4-2-8			TB11-4					
K5-2-9	K4-2-9			TB11-5					
K5-2-10	K4-2-10			TB11-7					
K5-2-11	K4-2-11			TB11-8					
K5-2-12	K4-2-12			TB11-11					
K5-1-1	K4-1-1			TB11-14					
K5-1-2	J2-c			TB8-14					
K4-2-6	K2-1-6	K5-2-6		TB10-8					

ID CONTROL PANEL

Exit Connector	Patch Panel	Connector or Relay	Circuit Information
1	25		Focus Command ID-1
2	26	J15-m	Focus (+) ID-1
3	27	J15-z	Focus (+) ID-2
4	28	J15-Y	Shutter ID-2 Limit Switch CLOSED
5	29	J15-Z	Shutter ID-2 Limit Switch OPEN
6	30		Focus Command ID-2
7	31	J15-HH	Shutter Motor ID-2 RED
8	32	J15-JJ	Shutter Motor ID-2 GREEN
9	33	J15-x	Channel A Vertical ID-3
10	34	J15-w	Channel A Horizontal ID-3
11	35	J15-a	Shutter ID-3 Limit Switch CLOSED
12	36	J15-b	Shutter ID-3 Limit Switch OPEN
13	37		Spare
14	38	EK3-1-6/EK4-2-7	Shutter Motor ID-3 RED
15	39	EK3-1-7/EK4-2-6	Shutter Motor ID-3 GREEN
16	40	EK4-1-6	Channel B Vertical ID-4
17	41	EK4-1-7	Channel B Horizontal ID-4
18	42	J15-c	Shutter ID-4 Limit Switch CLOSED
19	43	J15-d	Shutter ID-4 Limit Switch OPEN
20	44		Spare
21	45	EK4-1-5	Shutter Motor ID-4 RED
22	46	EK4-1-4	Shutter Motor ID-4 GREEN
23	47		Spare
24	48	J15-KK	Overload ID-2
25	49		Spare
26	50	EK3-1-8/EK4-2-8	Overload ID-3
27	51		Spare
28	52	EK4-1-9	Overload ID-4
29	53		Spare
30	54	EK3-1-5/EK4-2-5	Filter Encoder ID-3
31	55		Spare
32	56	EK4-1-3	Filter Encoder ID-4
33	57		Spare

ID CONTROL PANEL — con't.

Exit Connector	Patch Panel	Connector or Relay	Circuit Information
34	58	EK3-1-3/EK4-2-4	Filter Motor ID-3 RED
35	59	EK3-1-4/EK4-2-3	Filter Motor ID-3 GREEN
36	60		Spare
37	61	EK4-1-2	Filter Motor ID-4 RED
38	62	EK4-1-1	Filter Motor ID-4 GREEN
39	63		Thermo ID-3
40	64	J15-GG	Discriminator ID-3
41	65		Thermo PC
42	66	J15-LL	Discriminator ID-4/2
43	67		Thermo ID-4
44	68		Spare
45	33	J15-x	Channel A Vertical ID-2
46	34	J15-w	Channel A Horizontal ID-2
47	71		Focus Command ID-3
48	72		Focus Command ID-4
49	73	J15-y	Focus (+) ID-3
50	74	EK4-1-8	Focus (+) ID-4

DATA PANEL

1	1	J15-C	R_1 Signal
2	2	J15-AA	ηa BCD#1
3	3	EK4-2-12	ηb BCD#1
4	4	EK5-2-12	Filter Encoder PC-1
5	5	EK2-2-3	Filter Encoder PTG
6	6	EK5-1-1	Filter Encoder PC-2
7	7	EK2-2-2	Filter Motor PTG RED
8	8	EK5-2-9	Filter Motor PC-1 RED
9	9	EK2-2-1	Filter Motor PTG GREEN
10	10	EK5-2-8	Filter Motor PC-1 GREEN
11	11	EK2-2-4	Framing Motor PTG RED
12	12	EK5-2-11	Filter Motor PC-2 RED
13	13	EK2-2-5	Framing Lamp, Cycle PTG
14	14	EK5-2-10	Filter Motor PC-2 GREEN
15	15	EK2-2-6	PTG Calibration Lamp Line

DATA PANEL — con't.

Exit Connector	Patch Panel	Connector or Relay	Circuit Information
16	16	EK2-2-7	PTG Clock Lamp Line
17	17	EK2-2-8	PTG Shutter Motor RED
18	18	EK2-2-9	PTG Shutter Motor GREEN
19	19	EK2-2-11	PTG Shutter Limit Switch OPEN
20	20	EK2-2-10	PTG Shutter Limit Switch CLOSED
21	21	J15-u	a BCD#1
22	22	J15-v	a BCD#2
23	23	EK4-2-10	b BCD#1
24	24	EK4-2-11	b BCD#2

LOGIC PANEL

1	75	CARD	Aperture Step (+)
2	76	CARD	Aperture Step (-)
3	77	J15-L	Aperture Encoder Line #1
4	78	J15-M	Aperture Encoder Line #2
5	79	J15-N	Aperture Encoder Line #3
6	80	J15-P	Aperture Encoder Line #4
7	81	J15-R	Aperture Encoder Line #5
8	82	J15-S	Aperture Encoder Line #6
9	83	J15-T	Aperture Encoder Line #7
10	84	J15-U	Aperture Encoder Line #8
11	85	J15-V	Aperture Encoder Line #9
12	86	HV Supply	PC HV on Lamp Par 1
13	87	Hv Supply	PC HV on Lamp Par 2
14	88	EK5-2-7	PC Zero Control Line
15	89	EK5-2-4	PC Discriminator Control
16	90	EK5-1-2	PC Anode Overload
17	91	J15-f	PC Shutter Limit Switch OPEN
18	92	J15-e	PC Shutter Limit Switch CLOSED
19	93	EK5-2-6	PC Shutter Motor RED
20	94	EK5-2-5	PC Shutter Motor GREEN
21	95	J15-r	ω BCD#1
22	96	J15-s	ω BCD#2

LOGIC PANEL — con't.

Exit Connector	Patch Panel	Connector or Relay	Circuit Information
23	97	J15-t	ω BCD#4
24	98	J15-D	R_2 Signal

ES PANEL

1	99	J15-E	Mode Select MIRROR LS
2	100	J15-F	Mode Select CLOSED LS
3	101	J15-G	Mode Select APERTURE LS
4	102	J15-K	Detect Select CLEAR LS
5	103	J15-H	Detect Select B/S LS
6	104	J15-J	Detect Select PRISM LS
7	105	EK2-3-2-/EK3-2-2	Mode Select Motor BLACK
8	106	EK2-3-3/EK3-2-3	Mode Select Motor RED
9	107	EK2-3-4/EK3-2-4	Detect Select Motor RED
10	108	EK2-3-1/EK3-2-1	Detect Select Motor BLACK
11	109	EK2-2-12/EK3-1-2/ EK4-2-2	ID Calibration Lamp Line
12	110	CARD	Reverse Step Pulse Input
13	111		Spare
14	112		Spare
15	113		Spare
16	114		Spare

GUIDE PANEL

A	115	EK1-2-5	Base Ring Limit Switch CW
B	116	EK1-2-6	Base Ring Limit Switch CCW
C	117	EK1-2-7	Base Ring Limit Switch CCW
D	118	EK1-2-8	Base Ring Limit Switch CW
E	119	J15-W	Shutter ID-1 Limit Switch CLOSED
F	120	J15-EE	Shutter Motor ID-1 GREEN
G	121	J15-g	View/Guide Mirror ID-1 LS
H	122	J15-DD	View/Guide Mirror OPEN LS
J	123	EK1-1-5	Module I Limit Switch BETWEEN
K	124	J15-GG	View/Guide Mirror Motor BLACK
L	125	J15-CC	View/Guide Mirror Motor RED

GUIDE PANEL — con't.

Exit Connector	Patch Panel	Connector or Relay	Circuit Information
M	126	J15-h	View/Guide Morror ID-2 LS
N	127	J15-X	Shutter ID-1 Limit Switch OPEN
P	128	EK1-1-6	Module I Limit Switch IN
R	129	EK1-1-7	Module I Limit Switch OUT
S	130	J15-FF	Shutter Motor ID-1 RED
T	131	EK1-1-8	Module II Limit Switch BETWEEN
U	132	EK1-1-9	Module II Limit Switch OUT
V	133	EK1-1-10	Module II Limit Switch IN
W	134	J15-i	Deflection Vertical ID-1
X	135	J15-j	Deflection Horizontal ID-1
Y	136	J16-AA	Telescope Guidance Relay Command
Z	137	J16-DD	Spare
a	138	J16-BB	Σx IN
b	139	J16-EE	Spare
c	140	J16-CC	Σy IN
$\theta 1$	141	EK1-2-1	$\theta 1$ Motor Drive YELLOW
$\theta 2$	142	EK1-2-2	$\theta 2$ Motor Drive BLUE
$\theta 3$	143	EK1-2-3	$\theta 3$ Motor Drive RED
$\theta 4$	144	EK1-2-4	$\theta 4$ Motor Drive BLACK
R_1-1	145	EK1-2-9	R_1-1 Motor Drive YELLOW
R_1-2	146	EK1-2-10	R_1-2 Motor Drive BLUE
R_1-3	147	EK1-2-11	R_1-3 Motor Drive RED
R_1-4	148	EK1-2-12	R_1-4 Motor Drive BLACK
R_2-1	149	EK1-1-1	R_2-1 Motor Drive YELLOW
R_2-2	150	EK1-1-2	R_2-2 Motor Drive BLUE
R_2-3	151	EK1-1-3	R_2-3 Motor Drive RED
R_2-4	152	EK1-1-4	R_2-4 Motor Drive BLACK
A	153	K5-3-2	Var. Trans. T1 (+)
B	154	K5-3-3	Var. Trans. T1 (-)
C	155	K5-3-4	Var. Trans. T2 (+)
D	156	K5-3-5	Var. Trans. T2 (-)
E	157	K2-2-5/K3-2-5	Var. Trans. T3 (+)
F	158	K2-2-6/K3-2-6	Var. Trans. T3 (-)

Exit Connector	Patch Panel	Connector or Relay	Circuit Information
G	159	K2-2-7/K3-2-7	Var. Trans. T4 (+)
H	160	K2-2-8/K3-2-8	Var. Trans. Tr (-)
J	161	J16-A	Δδ Error Signal
K	162	J16-B	Δα Error Signal
L	163	J15-k	Var. Trans. Excitation
M			Var. Trans. Excitation
N			Spare
P			Spare
R			Spare
S			Spare

C δ

R,θ SWITCHING

Patch Panel	Relay (wipper -7 no.)	Exit Connector	Circuit Information
141	EK1-2-1	J17 A	θ1 Motor Drive YELLOW
142	EK1-2-2	J17 B	θ2 Motor Drive BLUE
143	EK1-2-3	J17 C	θ3 Motor Drive RED
144	EK1-2-4	J17 D	θ4 Motor Drive BLACK
115	EK1-2-5	J17 E	Base Ring Limit Switch CW N.C.
116	EK1-2-6	J17 F	Base Ring Limit Switch CCW N.C.
117	EK1-2-7	J17 G	Base Ring Limit Switch CCW C.
118	EK1-2-8	J17 H	Base Ring Limit Switch CW C.
145	EK1-2-9	J17 J	R_1-1 Motor Drive YELLOW
146	EK1-2-10	J17 K	R_1-2 Motor Drive BLUE
147	EK1-2-11	J17 L	R_1-3 Motor Drive RED
148	EK1-2-12	J17 M	R_1-4 Motor Drive BLACK
149	EK1-1-1	J17 N	R_2-1 Motor Drive YELLOW
150	EK1-1-2	J17 P	R_2-2 Motor Drive BLUE
151	EK1-1-3	J17 R	R_2-3 Motor Drive RED
152	EK1-1-4	J17 S	R_2-4 Motor Drive BLACK
123	EK1-1-5	J17 T	R_1 Limit Switch BETWEEN C. S2
128	EK1-1-6	J17 U	R_1 Limit Switch IN N.C. S3
129	EK1-1-7	J17 V	R_1 Limit Switch OUT N.C. S1
131	EK1-1-8	J17 W	R_2 Limit Switch BETWEE C. S5
132	EK1-1-9	J17 X	R_2 Limit Switch OUT N.C. S6
133	EK1-1-10	J17 Y	R_2 Limit Switch IN C. S4
	EK1-1-11	J17 Z	Spare
		J17 a	

PHOTOGRAPHIC

108	EK2-2-1	J17 A	Detector Select Motor BLACK
105	EK2-2-2	J17 B	Mode Select Motor BLACK
106	EK2-2-3	J17 C	Mode Select Motor RED
107	EK2-2-4	J17 D	Detector Select Motor RED
157	EK2-2-5	J17 E	Var. Trans. T3 (+)
158	EK2-2-6	J17 F	Var. Trans. T3 (-)
159	EK2-2-7	J17 G	Var. Trans. T4 (+)

PHOTOGRAPHIC — con't.

Patch Panel	Relay (wipper -7 no)	Exit Connector	Circuit Information
160	EK2-2-8	J17 H	Var. Trans. T4 (-)
109	EK2-2-9	J17 J	1.0 Calibration Lamp Lines
19	EK2-2-10	J17 K	Shutter Limit Switch PTG OPEN
20	EK2-2-11	J17 L	Shutter Limit Switch PTG CLOSED
18	EK2-2-12	J17 M	Shutter Motor PTG GREEN
9	EK2-1-1	J17 N	Filter Motor Photo GREEN
7	EK2-1-2	J17 P	Filter Motor Photo RED
5	EK2-1-3	J17 R	Encoder Filter Select
11	EK2-1-4	J17 S	Framing Motor Advance
13	EK2-1-5	J17 T	Framing Lamp
15	EK2-1-6	J17 U	Calibration Lamp Power Line
16	EK2-1-7	J17 V	Clock Lamp Power Line
17	EK2-1-8	J17 W	Shutter Motor RED
		J17 X	
		J17 Y	
		J17 Z	
		J17 a	
		J17 b	
		J17 c	

PHOTOMETRIC (ID-3)

Patch Panel	Relay (wipper -7 no)	Exit Connector	Circuit Information
108	EK3-2-1	J17 A	Detector Select Motor BLACK
105	EK3-2-2	J17 B	Mode Select Motor BLACK
106	EK3-2-3	J17 C	Mode Select Motor RED
107	EK3-2-4	J17 D	Detector Select Motor RED
157	EK3-2-5	J17 E	Var. Trans. T3 (+)
158	EK3-2-6	J17 F	Var. Trans. T3 (-)
159	EK3-2-7	J17 G	Var. Trans. T4 (+)
160	EK3-2-8	J17 H	Var. Trans. T4 (-)
50	EK3-2-9	J17 J	Overload ID-3
39	EK3-2-10	J17 K	Shutter Motor ID-3 GREEN
38	EK3-2-11	J17 L	Shutter Motor ID-3 RED
54	EK3-2-12	J17 M	Filter Encoder ID-3
63	EK3-1-1	J17 N	Temperature "3" Signal

PHOTOMETRIC (ID-3) — con't.

Patch Panel	Relay (wipper -7 no.)	Exit Connector	Circuit Information
109	EK3-1-2	J17 P	ID Calibration Lamp Line
58	EK3-1-3	J17 R	Filter Motor ID-3 RED
59	EK3-1-4	J17 S	Filter Motor ID-3 GREEN
		J17 T	
		J17 U	
		J17 V	
		J17 W	
		J17 X	
		J17 Y	
		J17 Z	
		J17 a	

PHOTOMETRIC (ID-3 and ID-4)

63	EK4-3-1	J17 A	Temperature "3" Signal
109	EK4-3-2	J17 B	ID Calibration Lamp
59	EK4-3-3	J17 C	Filter Motor ID-3 GREEN
58	EK4-3-4	J17 D	Filter Motor ID-3 RED
54	EK4-3-5	J17 E	Filter Encoder ID-3
39	EK4-3-6	J17 F	Shutter Motor ID-3 GREEN
38	EK4-3-7	J17 G	Shutter Motor ID-3 RED
50	EK4-3-8	J17 H	Overload ID-3
67	EK4-3-9	J17 J	Temperature "4" Signal
23	EK4-3-10	J17 K	b BCD 1
24	EK4-3-11	J17 L	b BCD 2
3	EK4-3-12	J17 M	ηb BCD 1
62	EK4-2-1	J17 N	Filter Motor ID-4 GREEN
61	EK4-2-2	J17 P	Filter Motor ID-4 RED
56	EK4-2-3	J17 R	Filter Encoder ID-4
52	EK4-2-4	J17 S	Overload ID-4
46	EK4-2-5	J17 T	Shutter Motor ID-4 GREEN
45	EK4-2-6	J17 U	Shutter Motor ID-4 RED
40	EK4-2-7	J17 V	Channel B Vertical Drive ID-4
41	EK4-2-8	J17 W	Channel B Horizontal Drive ID-4
74	EK4-2-9	J17 X	Channel B Focus (+) ID-4

PHOTOMETRIC (ID-3 and ID-4) — con't.

Patch Panel	Relay (wipper -7 no.)	Exit Connector	Circuit Information
105	EK4-2-10	J17 Y	Mode Select Motor BLACK
106	EK4-2-11	J17 Z	Mode Select Motor RED
107	EK4-2-12	J17 a	Detector Select Motor RED
108	EK4-1-1	J17 b	Detector Select Motor BLACK

PHOTOCELL

65	EK5-3-1	J17 A	Temperature PC
153	EK5-3-2	J17 B	Var. Trans. T1 (+)
154	EK5-3-3	J17 C	Var. Trans. T1 (-)
155	EK5-3-4	J17 D	Var. Trans. T2 (+)
156	EK5-3-5	J17 E	Var. Trans. T2 (-)
108	EK5-3-6	J17 F	Detector Select Motor BLACK
107	EK5-3-7	J17 G	Detector Select Motor RED
105	EK5-3-8	J17 H	Mode Select Motor BLACK
106	EK5-3-9	J17 J	Mode Select Motor RED
175 CARD	EK5-3-10	J17 K	Stepper Aperture GREEN/WHITE
176 CARD	EK5-3-11	J17 L	Stepper Aperture WHITE
177 CARD	EK5-3-12	J17 M	Stepper Aperture RED
178 CARD	EK5-2-1	J17 N	Stepper Aperture RED/WHITE
179 CARD	EK5-2-2	J17 P	Stepper Aperture GREEN
180 CARD	EK5-2-3	J17 R	Stepper Aperture BLACK
89	EK5-2-4	J17 S	Discriminator PC
94	EK5-2-5	J17 T	Shutter Motor PC GREEN
93	EK5-2-6	J17 U	Shutter Motor PC RED
88	EK5-2-7	J17 V	Zero PC
10	EK5-2-8	J17 W	Filter Motor PC-1 GREEN
8	EK5-2-9	J17 X	Filter Motor PC-1 RED
14	EK5-2-10	J17 Y	Filter Motor PC-2 GREEN
12	EK5-2-11	J17 Z	Filter Motor PC-2 RED
4	EK5-2-12	J17 a	Filter Encoder PC-1
6	EK5-1-1	J17 b	Filter Encoder PC-2
90	EK5-1-2	J17 c	Overload PC

No. 01114 -- Cable Wire List

Origin Connector	Pin	Termination Connector	Pin	Wire Size	Circuit Information
P6	A	P1	A	22	Multiplex Select Line #1
P6	B	P1	B	22	Multiplex Select Line #2
P6	C	P1	C	22	R_1 Signal
P6	D	P1	D	22	R_2 Signal
P6	E	P1	E	22	Mode Select MIRROR Limit Switch N.O.
P6	F	P1	F	22	Mode Select CLOSED Limit Switch N.O.
P6	G	P1	G	22	Mode Select APERTURE Limit Switch N.O.
P6	H	P1	H	22	Detector Select B/S Limit Switch N.O.
P6	J	P1	J	22	Detector Select PRISM Limit Switch N.O.
P6	K	P1	K	22	Detector Select CLEAR Limit Switch N.O.
P6	L	P1	L	22	Aperture Encoding Line #1
P6	M	P1	M	22	Aperture Encoding Line #2
P6	N	P1	N	22	Aperture Encoding Line #3
P6	P	P1	P	22	Aperture Encoding Line #4
P6	R	P1	R	22	Aperture Encoding Line #5
P6	S	P1	S	22	Aperture Encoding Line #6
P6	T	P1	T	22	Aperture Encoding Line #7
P6	U	P1	U	22	Aperture Encoding Line #8
P6	V	P1	V	22	Aperture Encoding Line #9
P6	W	P1	W	22	Shutter Limit Switch ID-1 CLOSED N.O.
P6	X	P1	X	22	Shutter Limit Switch ID-1 OPEN N.O.
P6	Y	P1	Y	22	Shutter Limit Switch ID-2 CLOSED N.O.
P6	Z	P1	Z	22	Shutter Limit Switch ID-2 OPEN N.O.
P6	a	P1	a	22	Shutter Limit Switch ID-3 CLOSED N.O.
P6	b	P1	b	22	Shutter Limit Switch ID-3 OPEN N.O.
P6	c	P1	c	22	Shutter Limit Switch ID-4 CLOSED N.O.
P6	d	P1	d	22	Shutter Limit Switch ID-4 OPEN N.O.
P6	e	P1	e	22	Shutter Limit Switch PC CLOSED N.O.
P6	f	P1	f	22	Shutter Limit Switch PC OPEN N.O.
P6	g	P1	g	22	View Guide Mirror ID-1 Limit Switch C
P6	h	P1	h	22	View Guide Mirror ID-2 Limit Switch C
P6	i	P1	i	22	Vertical Drive ID-1
P6	j	P1	j	22	Horizontal Drive ID-1

No. 01114 — con't.

Origin Connector	Pin	Termination Connector	Pin	Wire Size	Circuit Information
P6	k	P1	k	22	Var. Trans. Excitation
P6	m	P1	m	22	Focus ID-1
P6	n	P1	n	22	+28 VDC
P6	p	P1	p	22	+15 VDC
P6	q	P1	q	22	-15 VDC
P6	r	P1	r	22	ω BCD#1
P6	s	P1	s	22	ω BCD#2
P6	t	P1	t	22	ω BCD#4
P6	u	P1	u	22	ρa BCD#1
P6	v	P1	v	22	ρa BCD#2
P6	w	P1	w	22	Channel A Coil Line Horizontal ID-2/3
P6	x	P1	x	22	Channel A Coil Line Vertical ID-2/3
P6	y	P1	y	22	Channel A (+) Focus ID-3
P6	z	P1	z	22	Channel A(+) Focus ID-2
P6	AA	P1	AA	22	ηa BCD#1
P6	BB	P1	BB	22	View Guide Mirror Motor BLACK
P6	CC	P1	CC	22	View Guide Mirror Motor RED
P6	DD	P1	DD	22	View Guide Center Position Limit Switch C
P6	EE	P1	EE	22	Shutter Motor ID-1 GREEN
P6	FF	P1	FF	22	Shutter Motor ID-1 RED
P6	GG	P1	GG	22	Discriminator ID-3
P6	HH	P1	HH	22	Shutter Motor ID-2 RED
P6	JJ	P1	JJ	22	Shutter Motor ID-2 GREEN
P6	KK	P1	KK	22	Overload Signal ID-2
P6	LL	P1	LL	22	Discriminator ID-4/2
P6	MM	P1	MM	22	Spare
P6	NN	P1	NN	22	Spare
P6	PP	P1	PP		N/C
P7	A	P4	A	22	Δα Error Signal (J Box)
P7	B	P4	B	22	Δα Error Signal (J Box)
P7	C	P4	C	22	θ Readout Line #1
P7	D	P4	D	22	θ Readout Line #2
P7	E	P4	E	22	θ Readout Line #3
P7	F	P4	F	22	θ Readout Line #4

No. 01114 — con't.

Origin Connector	Pin	Termination Connector	Pin	Wire Size	Circuit Information
P7	G	P4	G	22	θ Readout Line #5
P7	H	P4	H	22	θ Readout Line #6
P7	J	P4	J	22	θ Readout Line #7
P7	K	P4	K	22	θ Readout Line #8
P7	L	P4	L	22	θ Readout Line #9
P7	M	P4	M	22	θ Readout Line #10
P7	N	P4	N	22	θ Readout Line #11
P7	P	P4	P	22	θ Readout Line #12
P7	R	P4	R	22	θ Readout Line #13
P7	S	P4	S	22	θ Readout Line #14
P7	T	P4	T	22	θ Readout Line #15
P7	U	P4	U	22	θ Readout Line #16
P7	V	P4	V	22	θ Readout Line #17
P7	W	P4	W	22	θ Readout Line #18
P7	X	P4	X	22	θ Readout Line #19
P7	Y	P4	Y	22	θ Readout Line #20
P7	Z	P4	Z	22	θ Readout Line #21
P7	a	P4	a	22	θ Readout Line #22
P7	b	P4	b	22	θ Readout Line #23
P7	c	P4	c	22	θ Readout Line #24
P7	d	P4	d	22	θ Readout Line #25
P7	e	P4	e	22	θ Readout Line #26
P7	f	P4	f	22	θ Readout Line #27
P7	g	P4	g	22	θ Readout Line #28
P7	h	P4	h	22	θ Readout Line #29
P7	i	P4	i	22	θ Readout Line #30
P7	j	P4	j	22	θ Readout Line #31
P7	k	P4	k	22	θ Readout Line #32
P7	m	P4	m	22	θ Readout Line #33
P7	n	P4	n	22	θ Readout Line #34
P7	p	P4	p	22	θ Readout Line #35
P7	q	P4	q	22	θ Readout Line #36
P7	r	P4	r	22	θ Readout Line #37
P7	s	P4	s	22	θ Readout Line #38

No. 01114 — con't.

Origin Connector	Pin	Termination Connector	Pin	Wire Size	Circuit Information
P7	t	P4	t	22	θ Readout Line #39
P7	u	P4	u	22	θ Readout Line #40
P7	v	P4	v	22	θ Readout Line #41
P7	w	P4	w	22	θ Readout Line #42
P7	x	P4	x	22	θ Readout Line #43
P7	y	P4	y	22	θ Readout Line #44
P7	z	P4	z	22	θ Readout Line #45
P7	AA	P4	AA	22	Telescope Guidance Relay Command
P7	BB	P4	BB	22	Σx in Error Signal
P7	CC	P4	CC	22	Σr in Error Signal
P7	DD	P4*	9" long	22	Spare
P7	EE	P4*	9" long	22	Spare
P7	FF	P4*	9" long	22	Spare
P7	GG	P01	A	22	Spare
P7	HH				N/C
P9	1**	P3	A	10	Ground Line #1
P9	2	P3	B	10	Ground Line #2
P9	3	P3	C	10	+5 VDC
P8	A	P2	A	22	Multiplex Circuit Line #1
P8	B	P2	B	22	Multiplex Circuit Line #2
P8	C	P2	C	22	Multiplex Circuit Line #3
P8	D	P2	D	22	Multiplex Circuit Line #4
P8	E	P2	E	22	Multiplex Circuit Line #5
P8	F	P2	F	22	Multiplex Circuit Line #6
P8	G	P2	G	22	Multiplex Circuit Line #7
P8	H	P2	H	22	Multiplex Circuit Line #8
P8	J	P2	J	22	Multiplex Circuit Line #9
P8	K	P2	K	22	Multiplex Circuit Line #10
P8	L	P2	L	22	Multiplex Circuit Line #11
P8	M	P2	M	22	Multiplex Circuit Line #12
P8	N	P2	N	22	Multiplex Circuit Line #13
P8	P	P2	P	22	Multiplex Circuit Line #14

* Tie back along outside of cable
** Splice and run to P4-PP GND

No. 01114 — con't.

Origin Connector	Pin	Termination Connector	Pin	Wire Size	Circuit Information
P8	R	P2	R	22	Multiplex Circuit Line #15
P8	S	P2	S	22	Multiplex Circuit Line #16
P8	T	P2	T	22	Multiplex Circuit Line #17
P8	U	P2	U	22	Multiplex Circuit Line #18
P8	V	P2	V	22	Multiplex Circuit Line #19
P8	W	P2	W	22	Multiplex Circuit Line #20
P8	X	P2	X	22	Multiplex Circuit Line #21
P8	Y	P2	Y	22	Multiplex Circuit Line #22
P8	Z	P2	Z	22	Multiplex Circuit Line #23
P8	a	P2	a	22	Multiplex Circuit Line #24
P8	b	P2	b	22	Multiplex Circuit Line #25
P8	c	P2	c	22	Multiplex Circuit Line #26
P8	d	P2	d	22	Multiplex Circuit Line #27
P8	e	P01	B	22	Spare
P8	f	P01	C	22	Spare
P8	g	P01	D	22	Spare
P8	h				N/C
P8	j				N/C
P2	e	P4	DD	22	θ Motor Drive YELLOW
P2	f	P4	EE	22	θ Motor Drive BLUE
P2	g	P4	FF	22	θ Motor Drive BLACK
P2	h	P4	GG	22	θ Motor Drive RED
P2		P4	HH	22	Base Ring Limit Switch CW N.C.
P2	j	P4	JJ	22	Base Ring Limit Switch CCW N.C.
P2	k	P4	KK	22	Base Ring Limit Switch CCW C.
P2	m	P4	LL	22	Base Ring Limit Switch CW C.
P2	n	P4	MM	22	+15 VDC
P2	p	P4	NN	22	-15 VDC
P3-A		P4	PP	22	Ground

No. 01116 -- Cable Wire List

Origin Connector	Pin	Termination Connector	Pin	Wire Size	Circuit Information
P15	A	P10	A	22	Multiplex Select Line #1
P15	B	P10	B	22	Multiplex Select Line #2
P15	C	P10	C	22	R_1 Signal
P15	D	P10	D	22	R_2 Signal
P15	E	P10	E	22	Mode Select MIRROR Limit Switch N.O.
P15	F	P10	F	22	Mode Select CLOSED Limit Switch N.O.
P15	G	P10	G	22	Mode Select APERTURE Limit Switch N.O.
P15	H	P10	H	22	Detector Select B/S Limit Switch N.O.
P15	J	P10	J	22	Detector Select PRISM Limit Switch N.O.
P15	K	P10	K	22	Detector Select CLEAR Limit Switch N.O.
P15	L	P10	L	22	Aperture Encoding Line #1
P15	M	P10	M	22	Aperture Encoding Line #2
P15	N	P10	N	22	Aperture Encoding Line #3
P15	P	P10	P	22	Aperture Encoding Line #4
P15	R	P10	R	22	Aperture Encoding Line #5
P15	S	P10	S	22	Aperture Encoding Line #6
P15	T	P10	T	22	Aperture Encoding Line #7
P15	U	P10	U	22	Aperture Encoding Line #8
P15	V	P10	V	22	Aperture Encoding Line #9
P15	W	P10	W	22	Shutter Limit Switch ID-1 CLOSED N.O.
P15	X	P10	X	22	Shutter Limit Switch ID-1 OPEN N.O.
P15	Y	P10	Y	22	Shutter Limit Switch ID-2 CLOSED N.O.
P15	Z	P10	Z	22	Shutter Limit Switch ID-2 OPEN N.O.
P15	a	P10	a	22	Shutter Limit Switch ID-3 CLOSED N.O.
P15	b	P10	b	22	Shutter Limit Switch ID-3 OPEN N.O.
P15	c	P10	c	22	Shutter Limit Switch ID-4 CLOSED N.O.
P15	d	P10	d	22	Shutter Limit Switch ID-4 OPEN N.O.
P15	e	P10	e	22	Shutter Limit Switch PC CLOSED N.O.
P15	f	P10	f	22	Shutter Limit Switch PC OPEN N.O.
P15	g	P10	g	22	View Guide Mirror ID-1 Limit Switch C
P15	h	P10	h	22	View Guide Mirror ID-2 Limit Switch C
P15	i	P10	i	22	Vertical Drive ID-1
P15	j	P10	j	22	Horizontal Drive ID-1

No. 01116 — con't.

Origin Connector	Pin	Termination Connector	Pin	Wire Size	Circuit Information
P15	k	P10	k	22	Var. Trans. Excitation
P15	m	P10	m	22	Focus ID-1 (+)
P15	n	P10	n	22	+28 VDC
P15	p	P10	p	22	+15 VDC
P15	q	P10	q	22	-15 VDC
P15	r	P10	r	22	ω BCD#1
P15	s	P10	s	22	ω BCD#2
P15	t	P10	t	22	ω BCD#4
P15	u	P10	u	22	ℓa BCD#1
P15	v	P10	v	22	ℓa BCD#2
P15	w	P10	w	22	Channel A Coil Line Horizontal ID-2/3
P15	x	P10	x	22	Channel A Coil Line Vertical ID-2/3
P15	y	P10	y	22	Channel A Focus ID-3
P15	z	P10	z	22	Channel A Focus ID-2
P15	AA	P10	AA	22	ηa BCD#1
P15	BB	P10	BB	22	View Guide Mirror Motor BLACK
P15	CC	P10	CC	22	View Guide Mirror Motor RED
P15	DD	P10	DD	22	View Guide Mirror Position Limit Switch C
P15	EE	P10	EE	22	Shutter Motor ID-1 GREEN
P15	FF	P10	FF	22	Shutter Motor ID-1 RED
P15	GG	P10	GG	22	Discriminator ID-3
P15	HH	P10	HH	22	Shutter Motor ID-2 RED
P15	JJ	P10	JJ	22	Shutter Motor ID-2 GREEN
P15	KK	P10	KK	22	Overload Signal ID-2
P15	LL	P10	LL	22	Discriminator ID-4/2
P15	MM	P10	MM	22	Space
P15	NN	P10	NN	22	Space
P15	PP	P10	PP		N/C

No. 01118 -- Cable Wire List

P17	A	P12	A	22	Multiplex Circuit Line #1
P17	B	P12	B	22	Multiplex Circuit Line #2
P17	C	P12	C	22	Multiplex Circuit Line #3
P17	D	P12	D	22	Multiplex Circuit Line #4

No. 01118 — con't.

Origin Connector	Pin	Termination Connector	Pin	Wire Size	Circuit Information
P17	E	P12	E	22	Multiplex Circuit Line #5
P17	F	P12	F	22	Multiplex Circuit Line #6
P17	G	P12	G	22	Multiplex Circuit Line #7
P17	H	P12	H	22	Multiplex Circuit Line #8
P17	J	P12	J	22	Multiplex Circuit Line #9
P17	K	P12	K	22	Multiplex Circuit Line #10
P17	L	P12	L	22	Multiplex Circuit Line #11
P17	M	P12	M	22	Multiplex Circuit Line #12
P17	N	P12	N	22	Multiplex Circuit Line #13
P17	P	P12	P	22	Multiplex Circuit Line #14
P17	R	P12	R	22	Multiplex Circuit Line #15
P17	S	P12	S	22	Multiplex Circuit Line #16
P17	T	P12	T	22	Multiplex Circuit Line #17
P17	U	P12	U	22	Multiplex Circuit Line #18
P17	V	P12	V	22	Multiplex Circuit Line #19
P17	W	P12	W	22	Multiplex Circuit Line #20
P17	X	P12	X	22	Multiplex Circuit Line #21
P17	Y	P12	Y	22	Multiplex Circuit Line #22
P17	Z	P12	Z	22	Multiplex Circuit Line #23
P17	a	P12	a	22	Multiplex Circuit Line #24
P17	b	P12	b	22	Multiplex Circuit Line #25
P17	c	P12	c	22	Multiplex Circuit Line #26
P17	d	P12	d	22	Multiplex Circuit Line #27
P17	e	P12	e	22	Spare
P17	f	P12	f	22	Spare
P17	g	P12	g	22	Spare
P17	h	P12	h		N/C
P17	j	P12	j		N/C

No. 01119 -- Cable Wire List

J16	C	Pθ1	A	22	θ Readout Line #1
J16	D	Pθ1	B	22	θ Readout Line #2
J16	E	Pθ1	C	22	θ Readout Line #3
J16	F	Pθ1	D	22	θ Readout Line #4

No. 01119 — con't.

Origin Connector	Pin	Termination Connector	Pin	Wire Size	Circuit Information
J16	G	Pθ1	E	22	θ Readout Line #5
J16	H	Pθ1	F	22	θ Readout Line #6
J16	J	Pθ1	G	22	θ Readout Line #7
J16	K	Pθ1	H	22	θ Readout Line #8
J16	L	Pθ1	J	22	θ Readout Line #9
J16	M	Pθ1	K	22	θ Readout Line #10
J16	N	Pθ1	L	22	θ Readout Line #11
J16	P	Pθ1	M	22	θ Readout Line #12
J16	R	Pθ1	N	22	θ Readout Line #13
J16	S	Pθ1	P	22	θ Readout Line #14
J16	T	Pθ1	R	22	θ Readout Line #15
J16	U	Pθ1	S	22	θ Readout Line #16
J16	V	Pθ1	T	22	θ Readout Line #17
J16	W	Pθ1	U	22	θ Readout Line #18
J16	X	Pθ1	V	22	θ Readout Line #19
J16	Y	Pθ1	W	22	θ Readout Line #20
J16	Z	Pθ1	X	22	θ Readout Line #21
J16	a	Pθ1	Y	22	θ Readout Line #22
J16	b	Pθ1	Z	22	θ Readout Line #23
J16	c	Pθ1	a	22	θ Readout Line #24
J16	d	Pθ1	b	22	θ Readout Line #25
J16	e	Pθ1	c	22	θ Readout Line #26
J16	f	Pθ1	d	22	θ Readout Line #27
J16	g	Pθ1	e	22	θ Readout Line #28
J16	h	Pθ1	f	22	θ Readout Line #29
J16	i	Pθ1	g	22	θ Readout Line #30
J16	j	Pθ1	h	22	θ Readout Line #31
J16	k	Pθ1	i	22	θ Readout Line #32
J16	m	Pθ1	j	22	θ Readout Line #33
J16	n	Pθ1	k	22	θ Readout Line #34
J16	p	Pθ1	m	22	θ Readout Line #35
J16	q	Pθ1	n	22	θ Readout Line #36
J16	r	Pθ1	p	22	θ Readout Line #37
J16	s	Pθ1	q	22	θ Readout Line #38

No. 01119 — con't.

Origin Connector	Pin	Termination Connector	Pin	Wire Size	Circuit Information
J16	t	P01	r	22	θ Readout Line #39
J16	u	P01	s	22	θ Readout Line #40
J16	v	P01	t	22	θ Readout Line #41
J16		P01	u		N/C
J16		P01	v		N/C
J16		P01	w		N/C
J16		P01	x		N/C
J16		P01	y		N/C
J16		P01	z		N/C
J16		P01	AA		N/C
J16		P01	BB		N/C
J16		P01	CC		N/C
J16		P01	DD		N/C
J16	w	P01	EE	22	θ Readout Line #42
J16	x	P01	FF	22	θ Readout Line #43
J16	y	P01	GG	22	θ Readout Line #44
J16	z	P01	HH	22	θ Readout Line #45
		P01	JJ		N/C
		P01	KK		N/C
		P01	LL		N/C
		P01	MM		N/C
J16		P0	NN		N/C
			PP		N/C

No. 01120 -- Cable Wire List

P02	A	J4	C	22	θ Readout Line #1
P02	B	J4	D	22	θ Readout Line #2
P02	C	J4	E	22	θ Readout Line #3
P02	D	J4	F	22	θ Readout Line #4
P02	E	J4	G	22	θ Readout Line #5
P02	F	J4	H	22	θ Readout Line #6
P02	G	J4	J	22	θ Readout Line #7
P02	H	J4	K	22	θ Readout Line #8
P02	J	J4	L	22	θ Readout Line #9

No. 01120 — con't.

Origin Connector	Pin	Termination Connector	Pin	Wire Size	Circuit Information
Pθ2	K	J4	M	22	θ Readout Line #10
Pθ2	L	J4	N	22	θ Readout Line #11
Pθ2	M	J4	P	22	θ Readout Line #12
Pθ2	N	J4	R	22	θ Readout Line #13
Pθ2	P	J4	S	22	θ Readout Line #14
Pθ2	R	J4	T	22	θ Readout Line #15
Pθ2	S	J4	U	22	θ Readout Line #16
Pθ2	T	J4	V	22	θ Readout Line #17
Pθ2	U	J4	W	22	θ Readout Line #18
Pθ2	V	J4	X	22	θ Readout Line #19
Pθ2	W	J4	Y	22	θ Readout Line #20
Pθ2	X	J4	Z	22	θ Readout Line #21
Pθ2	Y	J4	a	22	θ Readout Line #22
Pθ2	Z	J4	b	22	θ Readout Line #23
Pθ2	a	J4	c	22	θ Readout Line #24
Pθ2	b	J4	d	22	θ Readout Line #25
Pθ2	c	J4	e	22	θ Readout Line #26
Pθ2	d	J4	f	22	θ Readout Line #27
Pθ2	e	J4	g	22	θ Readout Line #28
Pθ2	f	J4	h	22	θ Readout Line #29
Pθ2	g	J4	i	22	θ Readout Line #30
Pθ2	h	J4	j	22	θ Readout Line #31
Pθ2	i	J4	k	22	θ Readout Line #32
Pθ2	j	J4	m	22	θ Readout Line #33
Pθ2	k	J4	n	22	θ Readout Line #34
Pθ2	m	J4	p	22	θ Readout Line #35
Pθ2	n	J4	q	22	θ Readout Line #36
Pθ2	p	J4	r	22	θ Readout Line #37
Pθ2	q	J4	s	22	θ Readout Line #38
Pθ2	r	J4	t	22	θ Readout Line #39
Pθ2	s	J4	u	22	θ Readout Line #40
Pθ2	t	J4	v	22	θ Readout Line #41
Pθ2	u	J4			N/C
Pθ2	v	J4			N/C

No. 01120 — con't.

Origin Connector	Pin	Termination Connector	Pin	Wire Size	Circuit Information
Pθ2	w	J4			N/C
Pθ2	x	J4			N/C
Pθ2	y	J4			N/C
Pθ2	z	J4			N/C
Pθ2	AA	J4			N/C
Pθ2	BB	J4			N/C
Pθ2	CC	J4			N/C
Pθ2	DD	J4			N/C
Pθ2	EE	J4	w		θ Readout Line #42
Pθ2	FF	J4	x		θ Readout Line #43
Pθ2	GG	J4	y		θ Readout Line #44
Pθ2	HH	J4	z		θ Readout Line #45
Pθ2	JJ				N/C
Pθ2	KK				N/C
Pθ2	LL				N/C
Pθ2	MM				N/C
Pθ2	NN				N/C
	PP				N/C

No. 01128 -- Cable Wire List

P6	AA	P1	A	22	ηa BCD#1
P6	u	P1	B	22	ξa BCD#1
P6	v	P1	C	22	ζa BCD#1
P6	x	P1	D	22	Channel A Vertical ID-3
P6	w	P1	E	22	Channel A Horizontal ID-3
P6	a	P1	F	22	Shutter ID-3 Limit Switch CLOSED
P6	b	P1	G	22	Shutter ID-3 Limit Switch OPEN
P8	L	P1	H	22	Shutter Motor ID-3 RED
P8	K	P1	J	22	Shutter Motor ID-3 GREEN
P8	J	P1	K	22	Overload ID-3
P8	M	P1	L	22	Filter Encoder ID-3
P8	R	P1	M	22	Filter Motor ID-3 RED
P8	S	P1	N	22	Filter Motor ID-3 GREEN
P8	N	P1	P	22	Thermo ID-3

No. 01128 — con't.

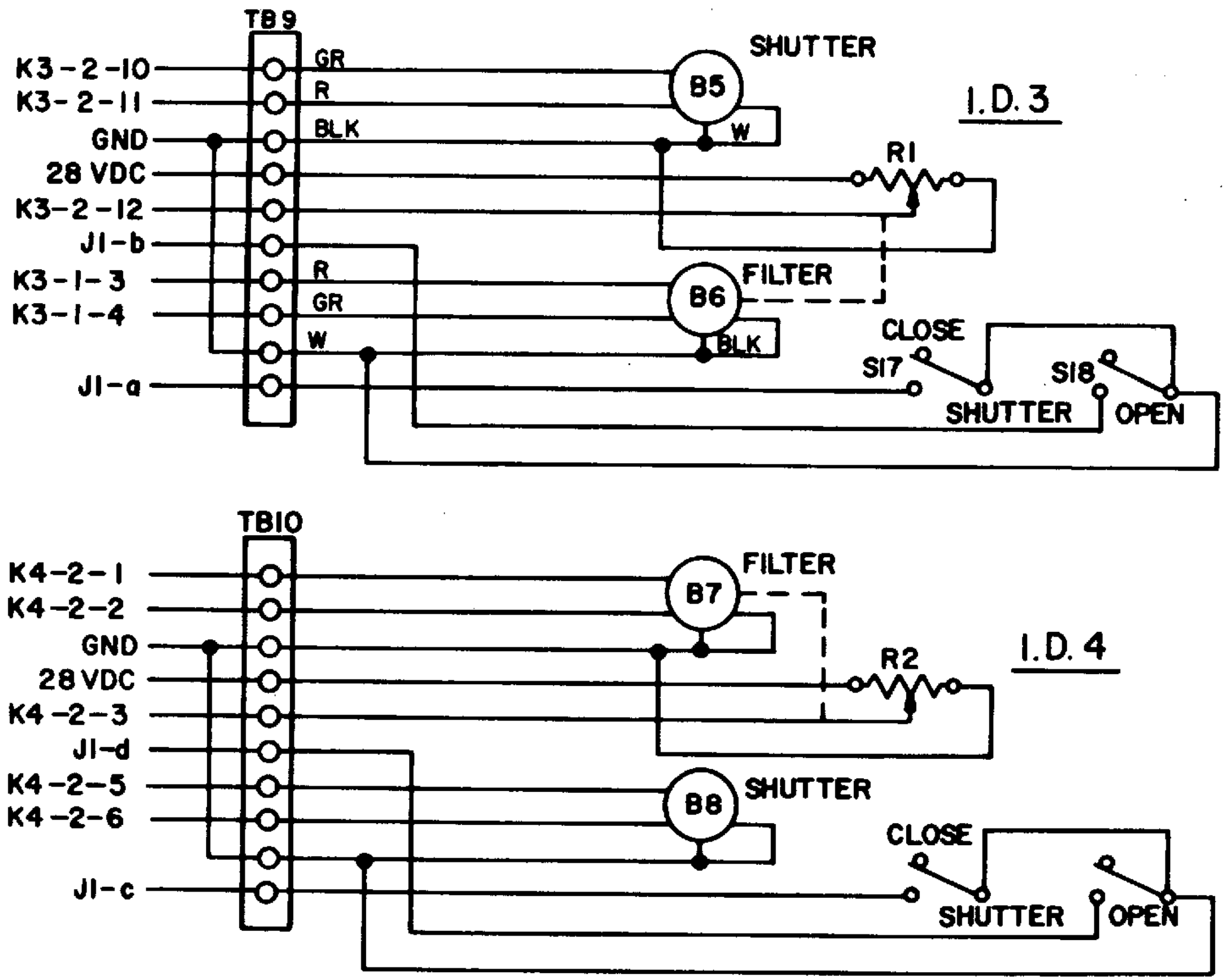
Origin Connector	Pin	Termination Connector	Pin	Wire Size	Circuit Information
P6	GG	P1	R	22	Discriminator ID-3
P6	y	P1	S	22	Focus (+) ID-3
P6	n	P1	T	22	+28 V
P6	p	P1	U	22	+15 V
P6	q	P1	V	22	-15 V
P6	r	P1	W	22	ω1
P6	s	P1	X	22	ω2
P6	t	P1	Z	22	ω4
P9	1	P1	a	10*	GND
		P1	b	10*	GND
		P1	c	10*	GND
		P1	d	10*	GND
		P1	e	10*	GND
		P1	f	10*	GND
P8	f	P1	g		Spare
P8	g	P1	h		Spare
P4	MM	P1	j	22	+15 V
P4	NN	P1	k	22	-15 V
		P1	m		N/C
P9	3	P1	n	10*	+5 V
		P1	p	10*	+5 V
		P1	r	10*	+5 V
		P1	s	10*	+5 V
P7	A	P4	A	22	Δα Error Signal
P7	B	P4	B	22	Δα Error Signal
P7	C	P4	C	22	θ Readout Line #1
P7	D	P4	D	22	θ Readout Line #2
P7	E	P4	E	22	θ Readout Line #3
P7	F	P4	F	22	θ Readout Line #4
P7	G	P4	G	22	θ Readout Line #5
P7	H	P4	H	22	θ Readout Line #6
P7	J	P4	J	22	θ Readout Line #7

* Distribute this single wire among pins noted

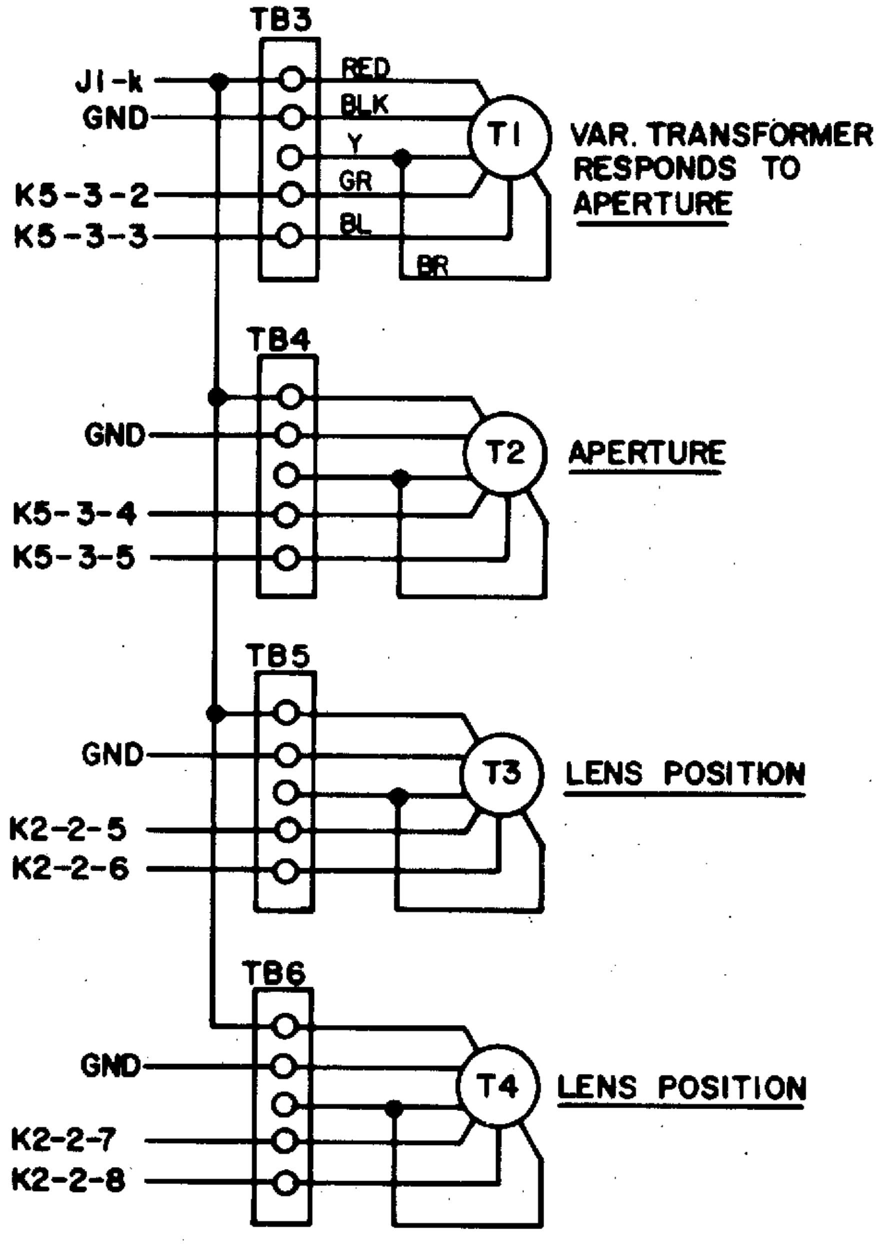
Origin Connector	Pin	Termination Connector	Pin	Wire Size	Circuit Information
P7	K	P4	K	22	θ Readout Line #8
P7	L	P4	L	22	θ Readout Line #9
P7	M	P4	M	22	θ Readout Line #10
P7	N	P4	N	22	θ Readout Line #11
P7	P	P4	P	22	θ Readout Line #12
P7	R	P4	R	22	θ Readout Line #13
P7	S	P4	S	22	θ Readout Line #14
P7	T	P4	T	22	θ Readout Line #15
P7	U	P4	U	22	θ Readout Line #16
P7	V	P4	V	22	θ Readout Line #17
P7	W	P4	W	22	θ Readout Line #18
P7	X	P4	X	22	θ Readout Line #19
P7	Y	P4	Y	22	θ Readout Line #20
P7	Z	P4	Z	22	θ Readout Line #21
P7	a	P4	a	22	θ Readout Line #22
P7	b	P4	b	22	θ Readout Line #23
P7	c	P4	c	22	θ Readout Line #24
P7	d	P4	d	22	θ Readout Line #25
P7	e	P4	e	22	θ Readout Line #26
P7	f	P4	f	22	θ Readout Line #27
P7	g	P4	g	22	θ Readout Line #28
P7	h	P4	h	22	θ Readout Line #29
P7	i	P4	i	22	θ Readout Line #30
P7	j	P4	j	22	θ Readout Line #31
P7	k	P4	k	22	θ Readout Line #32
P7	m	P4	m	22	θ Readout Line #33
P7	n	P4	n	22	θ Readout Line #34
P7	p	P4	p	22	θ Readout Line #35
P7	q	P4	q	22	θ Readout Line #36
P7	r	P4	r	22	θ Readout Line #37
P7	s	P4	s	22	θ Readout Line #38
P7	t	P4	t	22	θ Readout Line #39
P7	u	P4	u	22	θ Readout Line #40
P7	v	P4	v	22	θ Readout Line #41

No. 01128 — con't.

Origin Connector	Pin	Termination Connector	Pin	Wire Size	Circuit Information
P7	w	P4	w	22	θ Readout Line #42
P7	x	P4	x	22	θ Readout Line #43
P7	y	P4	y	22	θ Readout Line #44
P7	z	P4	z	22	θ Readout Line #45
P7	AA	P4	AA	22	Telescope Guidance Relay Command
P7	BB	P4	BB	22	Σx in Error Signal
P7	CC	P4	CC	22	Σy in Error Signal
P8	A	P4	DD	20	θ Motor Drive YELLOW
P8	B	P4	EE	20	θ Motor Drive BLUE
P8	C	P4	FF	20	θ Motor Drive BLACK
P8	D	P4	GG	20	θ Motor Drive RED
P8	E	P4	HH	22	Base Ring Limit Switch CW
P8	F	P4	JJ	22	Base Ring Limit Switch CCW
P8	G	P4	KK	22	Base Ring Limit Switch CCW
P8	H	P4	LL	22	Base Ring Limit Switch CW
P1	j	P4	MM	22	+15 VDC
P1	k	P4	NN	22	-15 VDC
P9	2	P4	PP	10	GND

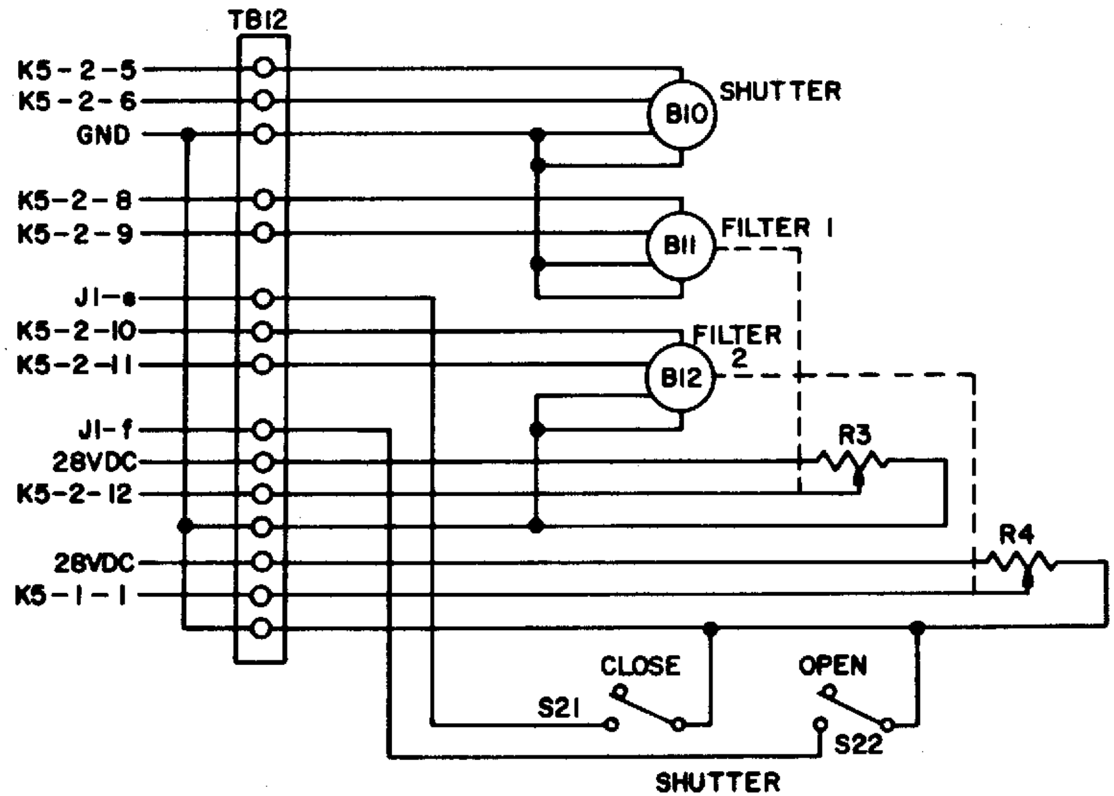


SCHEMATIC—I I.D. 3 & 4

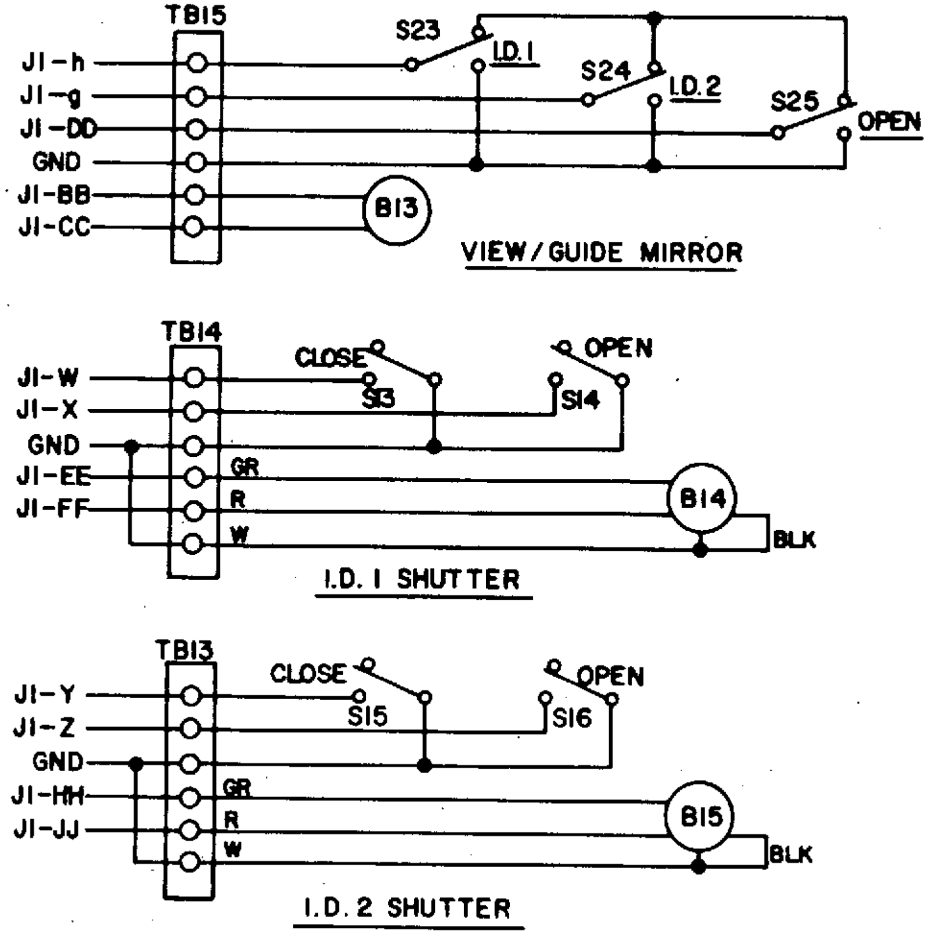


SCHEMATIC— 2 VARIABLE TRANSFORMER

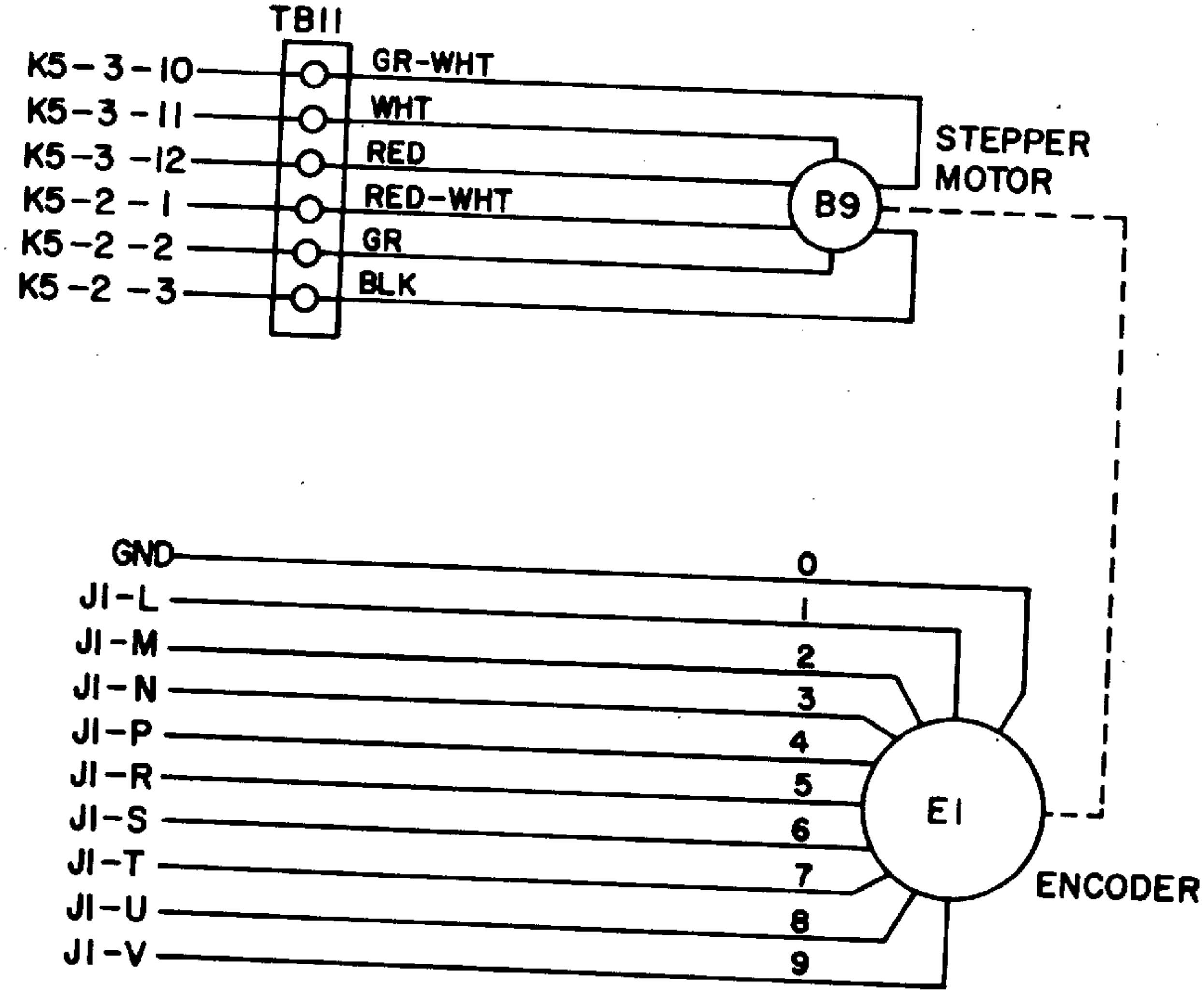
SCHEMATIC — 3 PHOTOMULTIPLIER



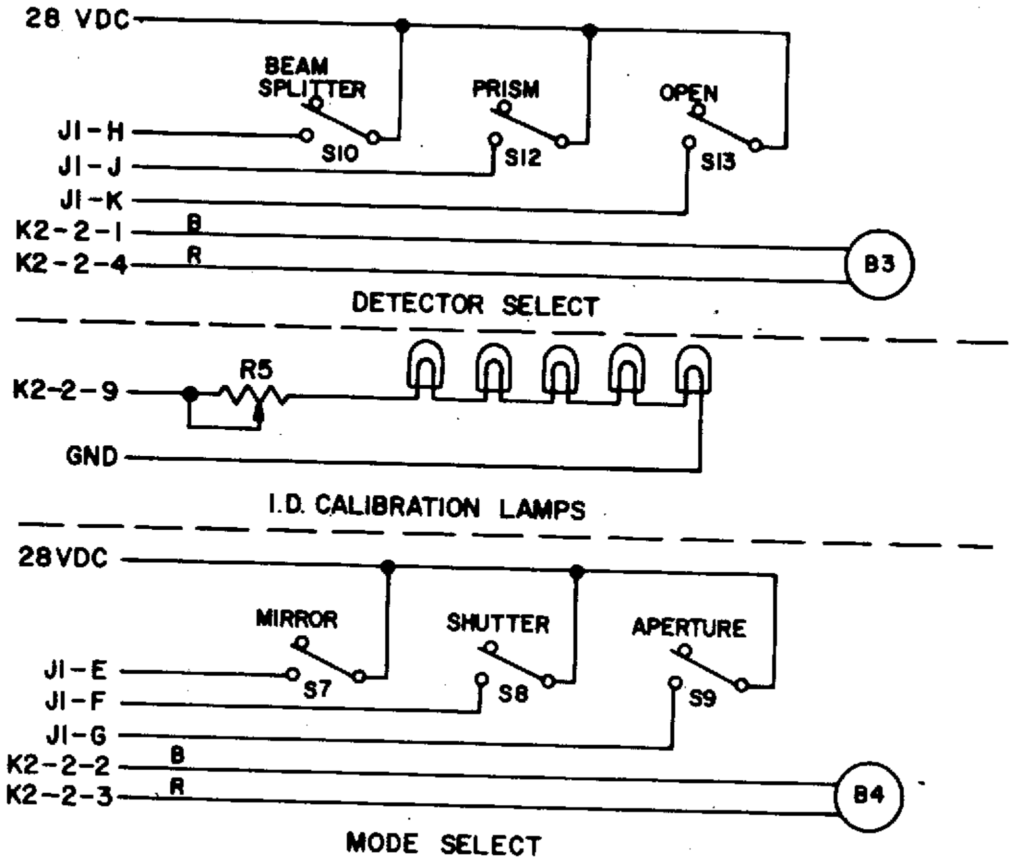
SCHEMATIC — 4

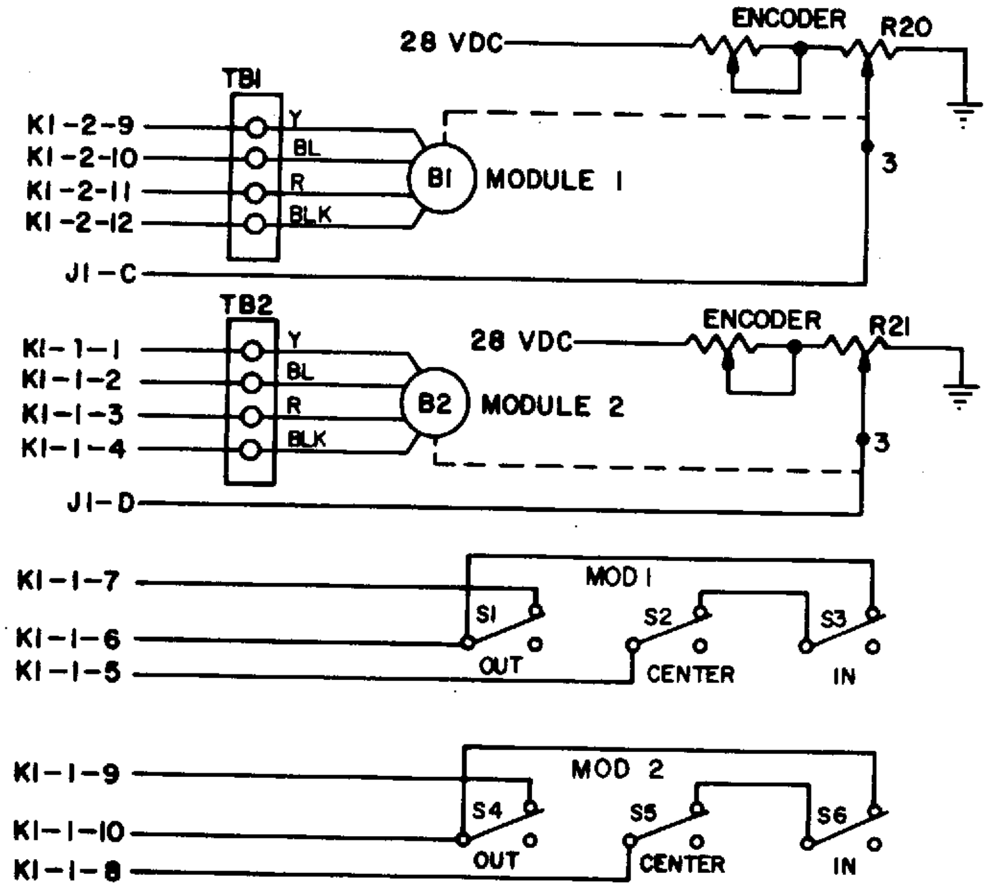

TB15
J1-h
J1-g
J1-DD
GND
J1-BB
J1-CC
S23
I.D.1
S24
I.D.2
S25
OPEN
B13
VIEW/GUIDE MIRROR
TB14
J1-W
J1-X
GND
J1-EE
J1-FF
CLOSE
S13
OPEN
S14
GR
R
W
B14
BLK
I.D. 1 SHUTTER
TB13
J1-Y
J1-Z
GND
J1-HH
J1-JJ
CLOSE
S15
OPEN
S16
GR
R
W
B15
BLK
I.D. 2 SHUTTER

SCHEMATIC — 5 APERTURE SELECT



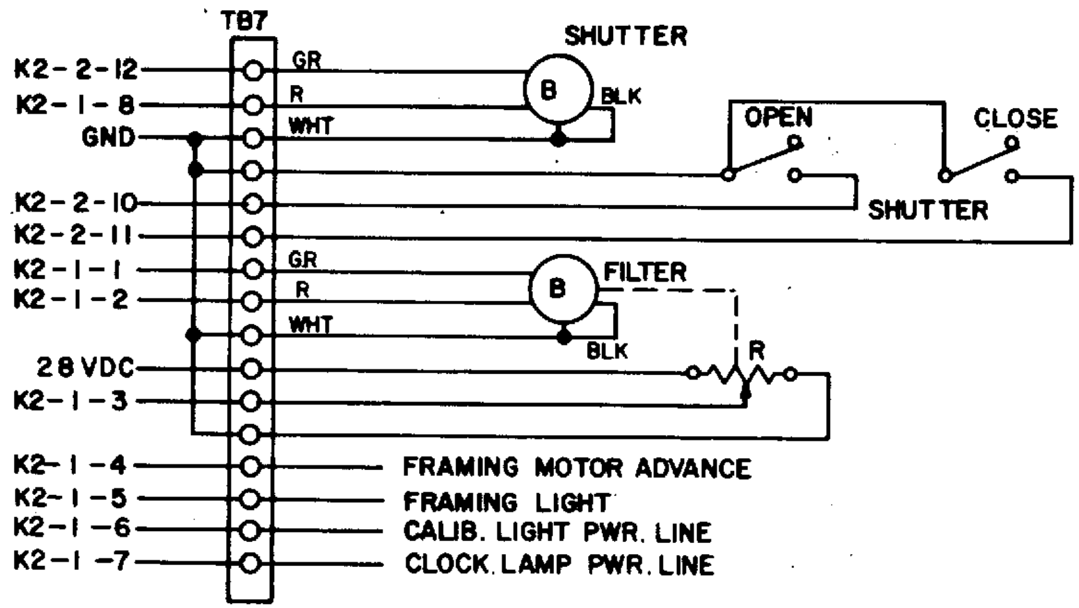
SCHEMATIC-6 DETECT, MODE SELECT & CALIB LAMPS



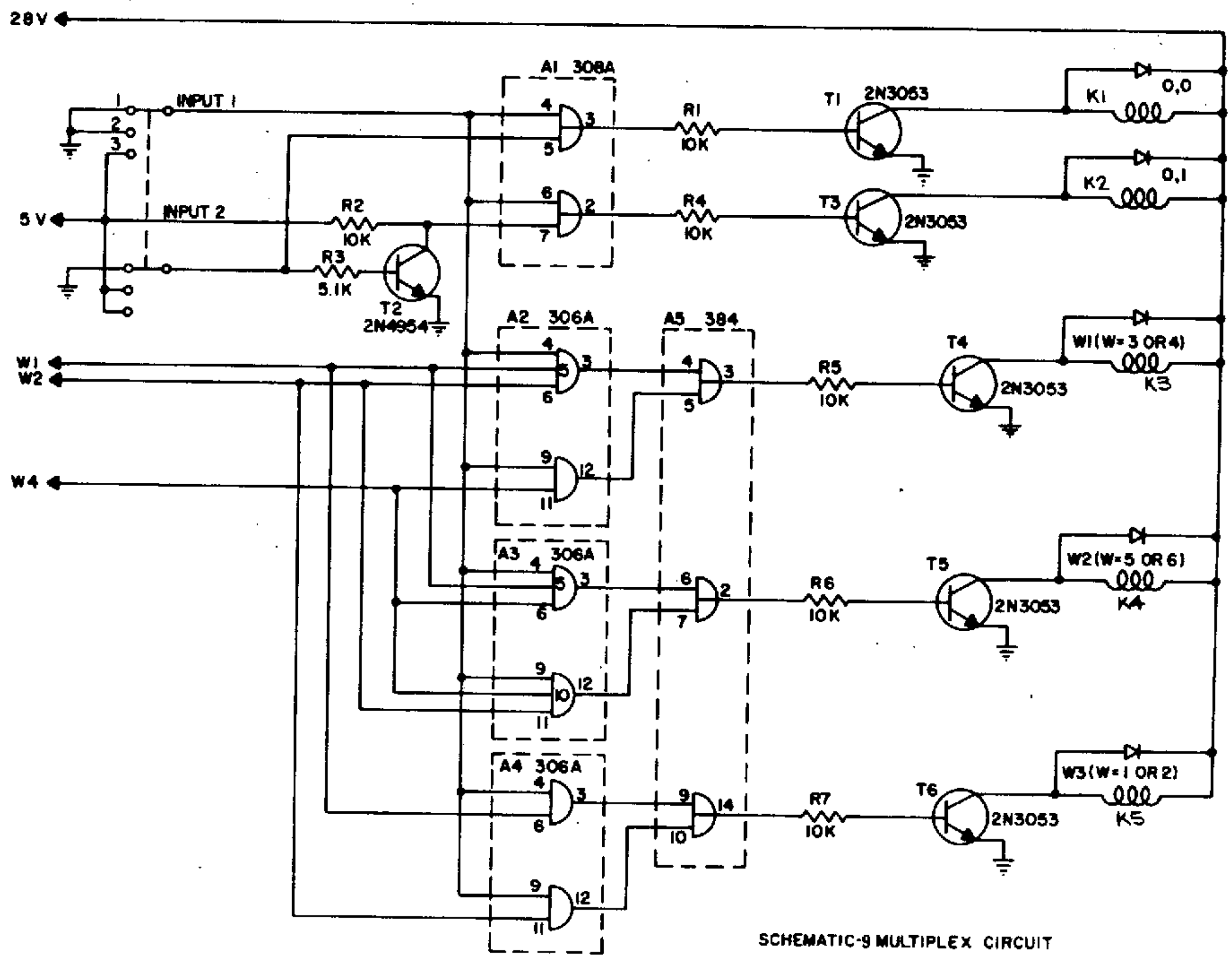


SCHEMATIC—7 MODULES 1 & 2

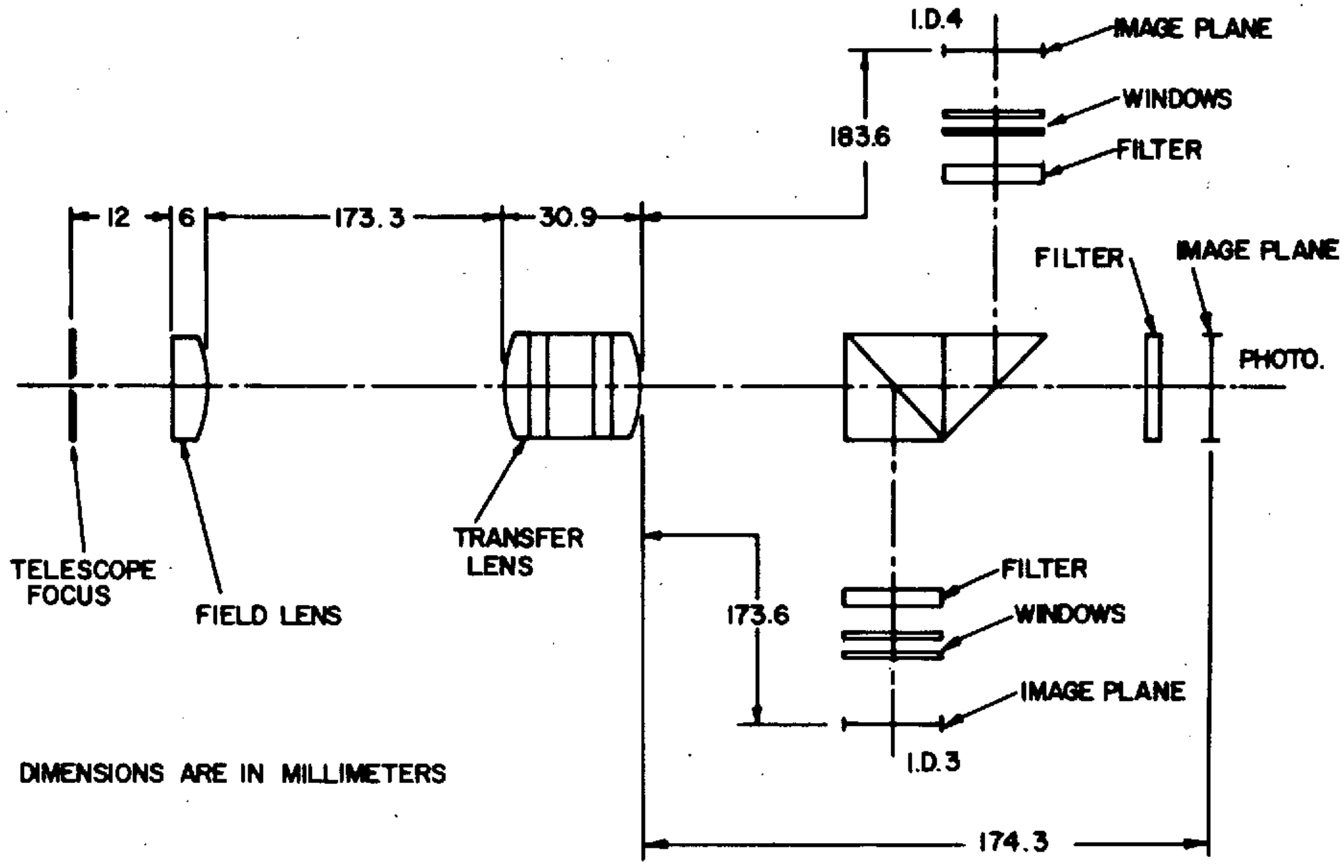
SCHEMATIC—8 PHOTOGRAPHIC



PHOTOGRAPHIC



SCHEMATIC-9 MULTIPLEX CIRCUIT



OPTICAL SCHEMATIC